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CHAWS DATA PROCESSING AND ANALYSIS TOOLS IN REAL-TIME AND POSTFLIGHT ENVIRONMENTS

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A number of different programs were used in the collection, calibration, display and analysis of data from the Charged Hazards and Wake Studies (CHAWS). The CHAWS experiment was flown on the Wake Shield Facility satellite during Space Shuttle missions STS-60 and STS-69 for studying plasma interactions with space vehicles and their wake. The programs utilized for the collection of real-time data during the two shuttle flights are described, as well as those used for the processing required to produce working postflight data bases. The real-time and postflight data visualization and analysis tools available from the CHAWS Analysis and Postflight Survey (CHAPS) software package are fully detailed. The CHUNKS software package, an extended data correlation tool, is also described.

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LIST OF ACRONYMS

ACS ..... Attitude Control System
AOS ..... Acquisition of Signal
ASCII .... American Standard Code of Information Interchange
CAS ..... Calibrated Ancillary System
CDD ..... Continuous Data Device
CHAWS .. Charging Hazards and Wake Studies
CHOMP .. CHAWS Orbital Monitoring Package
CHAPS ... CHAWS Analysis and Postflight Survey
CHUNKS . CHAWS UNpack Keyword System
DPU ..... Data Processing Unit
FES ...... Flash Evaporator System
GMT ..... Greenwich Mean Time
GSE ..... Ground Support Equipment
HV .... High Voltage
IPC ...... InterProcess Communication
LOS ..... Loss of Signal
LVLH ..... Local Horizontal Local Vertical
MCP ..... MicroChannel Plate
MET ..... Mission Elapsed Time
MPS ..... Main Propulsion System
NASA .... National Aeronautics and Space Administration
ODM ..... Orbital Downlink, Merged
ODRT .... Orbital Downlink, Real Time
ODPB .... Orbital Downlink, PlayBack
PDI ...... Packet Data Interleave
RCS ..... Reaction Control System
RMS ..... Remote Manipulator System
RPA ..... Retarding Potential Analyzer
STS ...... Space Transportation System
WSF ..... Wake Shield Facility

1. INTRODUCTION

1.1 CHAWS EXPERIMENT DESCRIPTION

The Charging Hazards and Wake Studies (CHAWS) experiment is a plasma diagnostics instrument for investigation of the interaction between large bodies in Low Earth Orbit and smaller bodies in their plasma wake. CHAWS was flown as a collaborative experiment on the Wake Shield Facility (WSF) on Space Shuttle missions STS-60 and STS-69. The improved understanding of spacecraft environmental interactions derived from CHAWS results will enhance the utilization of space.

The Wake Shield Facility (WSF) is a 12-foot diameter, stainless steel disk designed to generate an "ultra-vacuum" environment in space within which to grow thin semiconductor films for next-generation advanced electronics. The WSF is carried into orbit by the Space Shuttle, and is equipped with a cold gas propulsion system for separation from the orbiter and a momentum bias attitude control system. Hardware items used for the thin film production are located on the wake side of the WSF, while the batteries, electrical power system electronics packages, data acquisition and process control electronics, avionics and other support equipment are located on the ram side. The WSF is released into orbit by the orbiter RMS arm. The WSF maneuvers away from the Space Shuttle to a distance of 40 nautical miles, maintaining an orientation to shield out the residual atmosphere that remains in low earth orbit, thereby creating an ultra-pure vacuum in its wake, as shown in Figure 1.

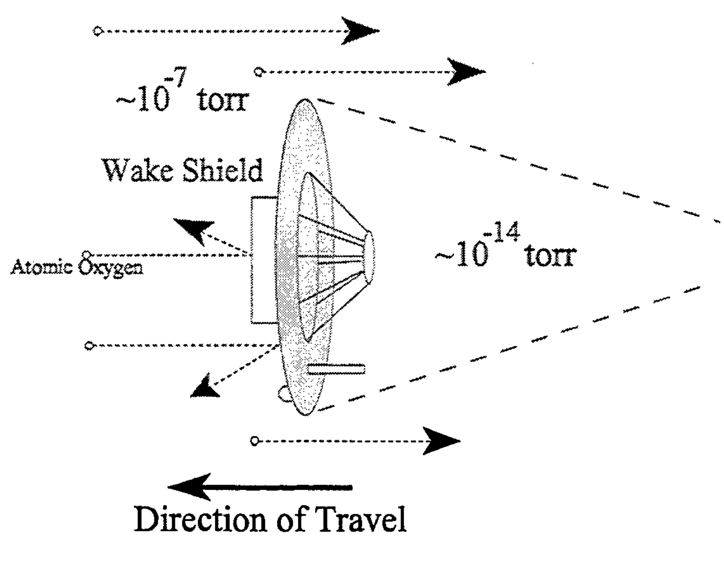


Figure 1. Wake Shield Facility.

The CHAWS experiment consists of two sensor units and a controller. The sensor units are equipped with a total of six compact particle detectors known as digital Retarding Potential Analyzers (RPAs). These small devices are capable of counting individual ions in the plasma stream. From these sensors, the composition, temperature, and flow direction of the plasma stream can be measured. Each RPA detector has been subdivided into two or four "channels", for a total of 16 subdivisions. The subdivisions allow for the particle flux direction vector to be derived from the channel count ratios.

Each RPA detector samples the incident particle flux through a small aperture, behind which are two retarding grids. A positive voltage bias on these grids allow the RPA detectors to perform limited particle mass discrimination of the incoming ions. The retarding voltage is swept from 0 to +32 volts in 1024 steps over a 7.5 second period, and the data are accumulated as a function of the sweep voltage. The particle flux transmitted though the grid system is measured by a microchannel plate (MCP) and anode assembly [*Violet and Bonito*, 1995].

Three RPA detectors are located on the ram side of the WSF, housed in a box with the center detector aperture perpendicular to the WSF surface and the inboard and outboard detectors canted at angles of +40 and -40 degrees from the center detector. See Figure 2.

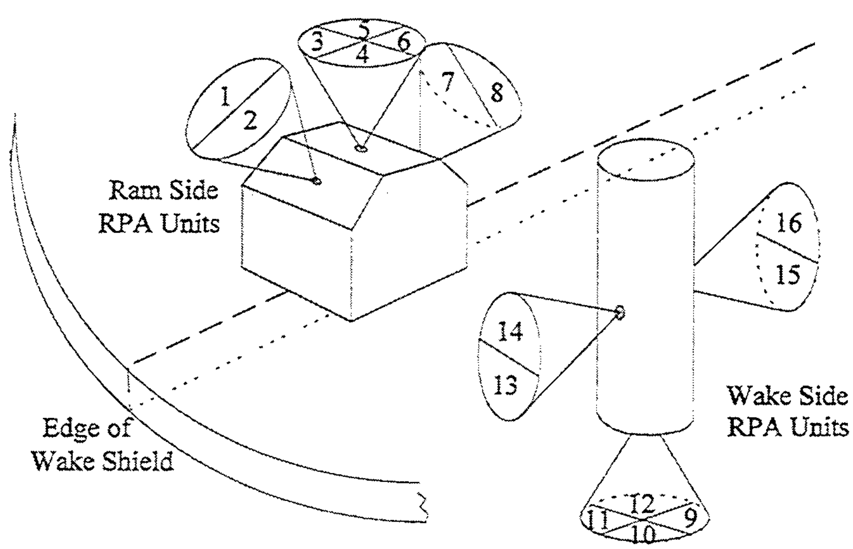


Figure 2. CHAWS instrument and detector fields of view.

The three RPA detectors on the wake side are integrated into the Langmuir Probe cylindrical housing. The center detector is located at the end of the cylinder and the inboard and outboard detectors are located midway on the side. Five current measurement points are also mounted on the probe; one at the tip, and four around the "waist". The Langmuir probe can be biased to high negative voltages to attract ions from

the edge of the plasma wake. The densities, spatial distributions, and plasma parameters of the attracted ions can be determined using the data from the different detectors and knowledge of the orientation of the WSF.

The CHAWS experiment has several objectives:

- To study the current collection behavior of a negatively-charged object in a plasma wake
- To test a new generation of compact particle detectors usable at extremely low densities
- To study the magnitude and directionality of the current collected by a negatively-charged object in the plasma wake as a function of the ambient-charged particle density and the orientation of the WSF and the Shuttle.
- To characterize the plasma wake environment in support of the WSF mission.

The CHAWS experiment conducts its primary investigation while the WSF is grappled by the orbiter RMS arm after retrieval of the WSF. The shuttle attitude and RMS arm position are varied to expose the sensors and allow the "mapping" of plasma wake around the Space Shuttle. As there are no data recorders on the WSF, all CHAWS data are collected in real time.

1.2 CHAWS RETARDING POTENTIAL ANALYZER CALIBRATIONS

Calibration data for both ram and wake RPA detectors were taken using the CALSYS/2 system and the MUMBO vacuum chamber *[Pakula and Cooke*, 1996]. This system enabled the sensors to be swept horizontally and vertically through an impinging beam of known strength. The measured data consisted of counts/sec in each of the sixteen micro-channel plate (MCP) detectors, for varying beam currents and different orientations. The calibration data were processed in terms of the summed response of each of the detector apertures to the currents. There were six cases to be treated: ram outboard (MCP 1,2), ram center (MCP 3-6), ram outboard (MCP 7,8), wake end (MCP 9-12), wake outboard (MCP 13,14), and wake inboard (MCP 15,16).

The calibration data for the RPA detectors were initially analyzed by fitting the measurements to analytic functions (trigonometric expansions and some variants of these), but this procedure was found not to give reliable and intuitive results in all cases due to the variability of the measurement data. Therefore a more direct method was used, that of reducing the data to manageable form by implementing an averaging procedure. The ram side averaging is based on a method which generates interpolated calibration data along lines emanating outwards from the center of each aperture. The lines data can then be averaged down to represent the response of each detector, as a function of the polar and

azimuth angles with respect to the aperture normal. The resulting calibrations files consist of a matrix of numbers, with the rows representing the response along the aperture polar angle and the columns giving the response with respect to the azimuth angle. Files of the same format were constructed for the wake side detectors, although the method of averaging varied according to each detector, due to the sparsity of the data.

Of the ram side cases, the central detector appears to be the most reliable, since it is based on all eight available measurement cases and does not have the added complication of a geometrical offset angle. The ram outboard data are based on just three available measurement cases, due to a late MCP replacement. The wake end detector data were averaged over all azimuth angles, assuming azimuthal symmetry. The wake inboard and output data were averaged for two measured horizontal CALSYS sweeps, ignoring azimuth angles. The procedures used in the CHAWS RPA detector calibrations are summarized in a separate technical report [*Tautz*, 1996].

The next level of detector analysis used the calibration files to determine the detector efficiencies as a function of Mach number. The resulting collection of calibration files are used by the CHAPS and CHUNKS data analysis applications, enabling flux and density values to be calculated.

2. REAL-TIME DATA PROCESSING

The collection and processing of CHAWS experiment data during on-orbit operations is vital to the project due to the lack of available on-board data recorders. With the availability of near real-time data, researchers are able to verify proper operation of the hardware and confirm that the correct conditions are present for each procedure. The near real-time data also allows for the instrument operating mode to be modified in response to observed events, maximizing the scientific value of data gathered. The archival of all available data permits postflight reprocessing for the extraction of other parameters for correlation in the data analysis process.

2.1 CHOMP

CHAWS Orbital Monitoring Package (CHOMP) is a Ground Support Equipment (GSE) laptop-based CHAWS data monitoring system. It has been designed to process and display information regarding the health and status of the CHAWS instrument. CHOMP provides textual and graphical displays, enabling users to confirm sensor activity and monitor performance. The package extracts the available CHAWS packets from the Wake Shield telemetry, and aligns each packet for further processing. The CHAWS asynchronous data frame is constructed from the aligned packets after a sync pattern search is performed. A complete CHAWS frame consists of 3571 bytes collected over 7.5 seconds, where a Wake Shield data frame of 1000 bytes is completed every 0.5 seconds.

These data frame rates were used in the design of a data display capability that allows the user to examine multiple data elements within a CHAWS frame. Users may to toggle between different CHAWS data displays at the Wake Shield frame rate. Although designed as a GSE program, CHOMP was also used on a laptop computer by the STS-69 crew during on-orbit CHAWS operations.

2.2 NASA ORBITER DOWNLINK DESCRIPTION

Two data streams are available from the NASA network connections. The ODRT (Orbiter Downlink, Real Time) stream is transmitted in real time at a rate of 128 kilobits/second during telemetry AOS periods. The ODPB (Orbiter Downlink, PlayBack) stream, recorded by the on-board orbiter telemetry recorders during LOS periods, is available from the NASA data center. When requested, the ODPB data are retransmitted by the data center at a rate of 192 kilobits/second, where the additional 64 kbits contain voice data. Through the archival of both types of orbiter downlink streams, the most complete telemetry data base can be reconstructed.

2.3 PC-DECOM DATA STREAM PROCESSING

PC-Decom is a PC-based software system that provides a user-defined interface to telemetered data. It allows the user to fully define the telemetry stream, data characteristics and display formats. [PCDECOM, 1990] For the STS-60 and STS-69 Space Shuttle missions, PC-Decom was configured for receiving the NASA Orbiter Downlink data in both real-time and playback modes. The PC is connected to the NASA CIP patch panel via four cables, two for 128-kbit real time, and two for 128-kbit playback data. Selected parameters for the orbiter, WSF and CHAWS are extracted from the 128-kbit real time data stream and displayed for telemetry monitoring. The 100% raw and "unpacked" orbiter, WSF and CHAWS data packets are relayed via Ethernet to the Sun workstations for archival and further processing.

2.4 LISTENER DATA STREAM PROCESSING

The Listener software receives the orbiter downlink telemetry as transmitted by the PC-Decom software. The Listener software examines packets received from the network via UDP protocol, and selectively extracts those for the CHAWS, WSF and orbiter data streams, as defined by a configuration data base. Master frame alignment is performed for proper synchronous transfer of the data. Mission-specific routines perform extraction, processing and archival of data.

The 100% raw ODRT and ODPB data streams transmitted by PC-Decom are archived without any further processing. These files are used in the reconstruction of postflight data bases. The CHAWS data packets are extracted from the 128-kbit real-time data stream, constructing each 7.5-second data frame as it is received. The CHAWS current values and instrument housekeeping values are calibrated. A WSF data frame is also constructed, calibrating the attitude information, pressure sensor values, and spacecraft housekeeping items. Selected portions of orbiter data are also extracted; further processing is required for converting the orbiter position information into True of Date coordinates and units of kilometers. The orbiter attitude pitch, yaw and roll values are calculated from the attitude quaternions. Data for the orbiter RMS arm angles, thruster firings and FES uses are decoded, and a model is used to calculate the orbiter's local magnetic field direction.

The Listener software places the data for each of the three types, CHAWS, WSF and orbiter, in separate shared memory segments, a standard Unix System V InterProcess Communication (IPC) facility. When a full frame of data is completed, the value of the System V IPC semaphore associated with that data type is changed to notify the data display processes of the CHAPS software package, described in a following section, that new data are available for access and display in near real-time. In addition to the IPC functions, the Listener software also writes the completed data frames to the appropriate data base files. These data base files allow for limited data review capabilities during real-time operations through specific CHAPS display processes.

3. POSTFLIGHT DATA PROCESSING

The merging of the archived raw data steams collected during real-time operations produces a nearly contiguous data set of the mission events. This merged data set is used as the input stream to a modified configuration of the real-time data processing system to create the final CHAWS, WSF and orbiter databases. These data bases serve as the input to the CHAPS and CHUNKS data analysis software packages in the postflight environment.

3.1 ORBITER DOWNLINK DATA STREAM MERGING

The 8-mm tapes containing the 100% raw Orbiter Downlink, Real Time (ODRT) and Orbiter Downlink, PlayBack (ODPB) data files are extracted onto a Sun workstation. Two sets of 8-mm archive tapes were generated during real-time operations to ensure that all data segments collected are available for postflight processing.

The ODRT data files are scanned using a script that reads all data timestamps, determines the integrity of the data and produces a listing of all data gaps occurring in each file. The ODPB data files are processed through a similar script that produces a listing of all time periods that are covered by the valid data segments contained in each playback file.

These listings are used to determine which ODPB files contain data to fill the gaps found in each ODRT file.

Each pair of ODRT and ODPB files to be merged are used as input to a program that produces a more complete output file. This is performed successively on each ODRT file until all needed data from the available ODPB files have been merged in. The resultant merged file is then input to another program for resequencing the PC-Decom DOS timestamps that exist in each data major frame header. This allows for the data segment to be run properly through PC-Decom in playback mode. These modified files are referred to as Orbiter Downlink, Merged (ODM) files.

3.2 POSTFLIGHT PC-DECOM DATA STREAM PROCESSING

PC-Decom was reconfigured to read input from a specific ODM file rather than from the ODRT or ODPB data lines. The ODM files were transferred to the PC in chronological order and supplied as input to PC-Decom for reprocessing. As during real-time operations, the output of PC-Decom was transmitted to the Listener Process on an adjacent Sun workstation via Ethernet.

3.3 LISTENER REGENERATION OF DATA BASES

The Listener software is also reconfigured for postflight data processing. The data stream archival option is turned off, and the interprocess communication features are suspended. Only the processed data base files, used by the CHAPS and CHUNKS data analysis software packages, are generated.

3.4 CHAWS DATA BASE ENHANCEMENTS

The CHAWS telemetry data time code was transformed into the actual Greenwich Mean Time (GMT). The CHAWS DPU "power on" PDI time was used as an initial GMT reference and the CHAWS time code value was added to obtain the estimated GMT. To account for a slow drift rate, each of the operation periods were examined and fitted to a linear equation. Each operational segment time code was then corrected by the associated drift rate. The correlation of the orbiter thruster events and the CHAWS MCP data response was used to confirm proper GMT transformation.

4. CHAPS DATA ANALYSIS PROCESSING

The CHAWS Analysis and Postflight Survey (CHAPS) software is a comprehensive collection of applications for viewing CHAWS data and associated space vehicle information in many different graphical and textual forms simultaneously. The CHAPS software, designed to operate on Sun workstations, uses a simple and self-explanatory user interface. Using standard Unix System V InterProcess Communication (IPC) shared memory segments and semaphore sets, each of the active CHAPS displays independently accesses and processes data from the shared data stream, producing the concurrent user-selected data displays for analysis. During real-time CHAPS operations, the data from the current CHAPS operations, as well as the related Wake Shield Facility (WSF) and Space Shuttle parameters, are viewed in real-time as received via the telemetry data as provided by the Listener software, described earlier. Postflight CHAPS operations provide a master data control process, allowing the user to specify the time for surveying the available experiment data, and feature data display processes virtually identical to those used in real-time operations. While surveying the experiment data, the user may build and maintain a working data base of times of interest.

4.1 CHAPS COMMAND PROCESS

The command process panel, shown in Figure 3, is the main-level user interface for invoking all CHAPS display processes. The user simply selects the desired display process specified on the command panel buttons or pull-down menus. As each process is invoked or exited, an informative message is displayed on the base of the command panel. The user may select the color scaling mode of the graphical display processes being invoked. In the "Color" mode, the invoked graphical displays are in full color on a black background. In the "Grey" mode, the invoked graphical displays use a grey-shade scale, except for line type displays which use a black-and-white scale. The "Invert" checkbox changes the color scale so that the background is white. For "inverted color" mode, a slightly altered version of the familiar color scale is used. The "inverted grey" mode uses is an inverted grey scale. The CHAPS command process governs all display processes and the interprocess communication facilities used by them. Pressing the command panel "Quit" button, when confirmed, will cause all active display processes to exit.

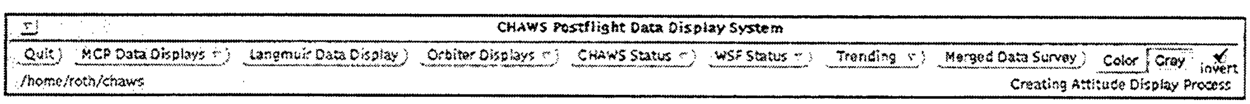


Figure 3. CHAPS Command Process panel.

4.2 LISTENER (REAL-TIME ONLY)

As described in Section 2.4, the Listener software processes telemetry data packets, building the data frame segments for archival to disk and sharing them with the data display processes. The CHAWS, WSF, and Orbiter data streams are loaded in separate shared memory segments, and the appropriate semaphore signal is set when new data is available to the display processes.

4.3 LISTENER LOG (REAL-TIME ONLY)

The Listener Log process allows the user to monitor the status of the Listener software during real-time flight operations. Error or diagnostic messages are viewed in this window, along with logging of specific events, such as a change of archive data files being written, command echoing of the instrument, the recalculation of the M50-to-True of Date conversion matrix, or detection of data stream drop outs.

4.4 DATA MONITOR (REAL-TIME ONLY)

The data monitor allows the user to monitor the flow of data to the display processes during real-time flight operations. The current Orbiter Mission Elapsed Time (MET), the Wake Shield Facility (WSF) Packet Data Interleave (PDI) time, and CHAWS time codes are continually updated. Watching this display allows the user to quickly check which data streams are being received and distributed by the Listener process.

4.5 MERGE SURVEY (POSTFLIGHT ONLY)

The Merge Survey process takes the place of the Listener and Data Monitor processes in the postflight data analysis environment. The Merge Survey process loads time-synchronized CHAWS, WSF, and Orbiter data streams in their respective shared memory segments and sets the corresponding semaphore signal, emulating the IPC operations of the Listener process. This allows the real-time data display processes to be used in the postflight environment virtually unchanged. The Merge Survey process gives the user complete control over the data flow: the user specifies a starting time, and may vary the rate at which the data is loaded in the shared memory and processed by the various displays. During data loading, the current CAS GMT and MET, WSF PDI and CHAWS GMT times are displayed, as shown in Figure 4. The user may also save the times of data events with an associated text label, as shown in Figure 5. These user-defined times may be recalled through the scrolling list of times.

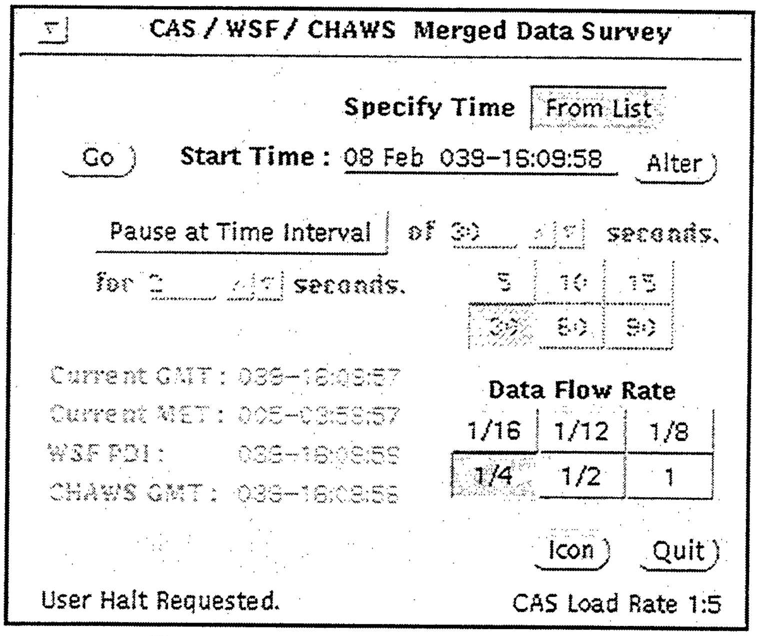


Figure 5. Merge Survey Control panel.

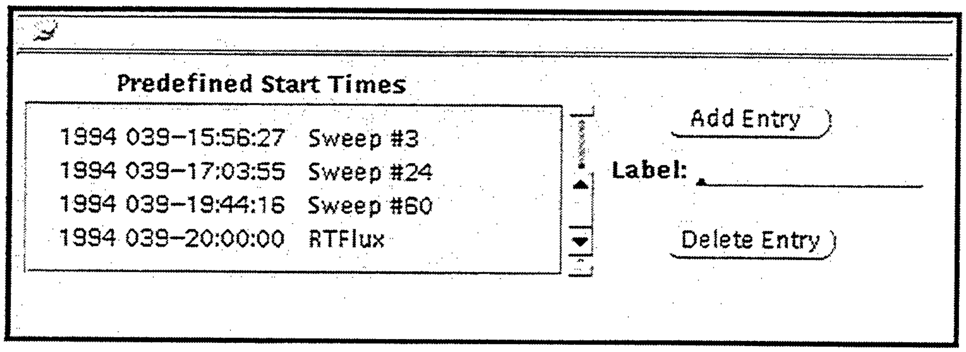


Figure 4. Time Data Base Selection panel.

In the postflight data analysis environment, all interprocess communication facilities used for the data merging and display processes are separated based on system user account identification numbers. This distinction allows multiple users to conduct simultaneous data analysis sessions without interfering with each others' data display processes.

4.6 CHAWS MCP DATA CALIBRATIONS

Each data analysis process accesses the shared data stream, populated by the Listener or Merge Survey process, and independently performs the required calibrations according to their function.

All data calibrations are performed by a set of algorithms common to all data analysis processes so that consistency is maintained. The four types of available calibrations are described in Table 1.

TABLE 1. CHAWS MCP Data Calibrations		
Calibration Type	**Ram Side MCP Data**	**Wake Side MCP Data**
Raw Counts	*telemetry counts*	*expanded telemetry counts*
Count Rate (counts/second)	$\textit{telemetry counts} \times 2 \times \textit{time calibration}$	$\textit{expanded telemetry counts} \times \textit{time calibration}$
Flux	$\textit{telemetry counts} \times 2 \times \textit{time calibration} \times \textit{flux calibration factor}$	$\textit{expanded telemetry counts} \times \textit{time calibration} \times \textit{flux calibration factor}$
Density	$\textit{telemetry counts} \times 2 \times \textit{time calibration} \times \textit{density calibration factor}$	$\textit{expanded telemetry counts} \times \textit{time calibration} \times \textit{density calibration factor}$

The wake side MCP data values are encoded in a log format because of limited telemetry bandwidth, and therefore require expansion before processing.

The $$\textit{time calibration} = \frac{1024.0}{\textit{time dwell} \times 7.5}$$

normalizes the MCP data measurements based on the time duration of their data collection, as specified by the *time dwell* value. The *time dwell* value is a function of RPA Step number, as shown in Table 2.

TABLE 2. Time Dwell Values	
RPA Step Range	*time_dwell* value
1-64	2
65-96	4
97-128	8
129-160	16

The flux and density calibration factor values are aperture-specific and ram direction-dependent. Their values are defined as follows:

$$\textit{flux calibration factor} = \frac{1.0}{G_{flux}(Mach, Azimuth, Elevation) \times G_0 \times Prefactor}$$

$$\textit{density calibration factor} = \frac{1.0}{G_{density}(Mach, Azimuth, Elevation) \times G_0 \times Prefactor \times V_d}$$

The calibration factors used are based on the geometric function (G_{flux} and $G_{density}$) values read from the calibration files in the CHAPS installation directory. The 20 calibration files are organized on the basis of aperture side (ram or wake), calibration type (flux or density), and the five available Mach numbers (0, 1, 3, 5 and 9). The averaged geometric factor for an isotropic distribution (G_0), the *Prefactor*, which incorporates the aperture area and efficiency factors, and the orbital velocity (V_d) values are also contained in each of these files.

For all apertures, the ram direction azimuth angle = 0° is defined to be in the "-Y" axis direction of the WSF body coordinates, and increases in the counter-clockwise direction about the aperture normal. The ram direction elevation is defined as the angle between the ram direction and the aperture normal.

4.7 WSF STATUS DETERMINATION

The CHAWS data flux and density calibrations depend on the orientation of the velocity vector relative to the CHAWS MCP apertures. The current WSF status is required for determining the types of calculations to be performed in order to produce the velocity vector direction with respect to the WSF body. When the WSF status is *Stowed*, only the orbiter attitude is required for determining the WSF body attitude. When *Grappled* (by the orbiter RMS arm end effector), a series of translations and rotations are used to account for the various RMS joint angles and section lengths, and then the orbiter attitude. When *Deployed* (free-flying), only the WSF attitude values are needed. With the WSF body orientation known, the required angles can be calculated, including the WSF Ram and B-field angles and the CHAWS aperture ram direction elevation and azimuth angles. A standard testing procedure to determine the WSF status is followed in the processes which calculate these angles :

1. Initially, the WSF status is assumed to be *Stowed*
2. If the WSF ACS Power is "on", then WSF status is *Deployed*
3. If the orbiter RMS "payload captured" bit is set, then WSF status is *Grappled*;

The WSF status testing procedure is used by the Attitude, CHAWS Ram Direction, CHAWS MCP, CHAWS Langmuir and Calibration Globe display processes and their associated pullout line graph processes. Each of these processes are fully described in the following sections.

4.8 COLOR SCALING OF COLOR RASTER IMAGES

The CHAWS MCP and Langmuir Display processes, both of which are described below, present the data as raster images of up to 33 colors. The color and data value scale on the right side of the frame shows a stack of 32 colors with associated data scale values, representing the full dynamic range of the data being displayed. The color at the bottom of the scale represents values at or below the lower limit of the data scaling. The color at the top represents the data "Saturation" level, being 10 times the upper limit of the data scaling. These data scaling limits have been prescribed by the CHAWS investigators, and are defined at program compilation time. Grey is the 33rd color. Although not contained in the color scale stack, this color is used to indicate data values which exceed the data scale saturation level or data values whose calibration factor has been deemed invalid (i.e. =0.0).

The color scale used by each graphical display is dependent on the "Color/Grey/Invert" user selections on the command bar at the time the display is created. Any child displays inherit their parent process color mode. Such selections allow the user to view the data analysis displays as suited to their needs and/or preferences. The inverted mode is especially useful for generating data displays to be included in publications.

4.9 CHAWS MCP DATA DISPLAY

The CHAWS MCP Data Display presents three parallel color raster images of selectively summed MCP data from the ram or wake side apertures over the RPA steps, versus time. An example is shown in Figure 6. Each of the three data raster images may be configured to display data from one to several of the MCP units, in one of several calibration types. The configured summations may be displayed in Raw Counts, Count Rate, Flux or Density calibrations. Such raster images allow the user to perform qualitative data analysis. Associated line graph pullouts may be invoked directly from the color raster images, allowing the user to perform quantitative data analysis in parallel. The default configurations sums all MCP units of each of the three apertures on either side.

For each CHAWS data frame, the telemetry counts (Ram Side MCPs) or the expanded counts (Wake Side MCPs) of the selected MCP units are summed for each of the 160 RPA steps, resulting in 160 summed Raw Count values. For further calibration, each of these raw count sums are then multiplied by the appropriate dwell time correction (and by 2 for Ram Side MCPs only), resulting in 160 Count Rate values. To obtain the Flux or Density calibrated values, the Count Rate values are multiplied by the flux or density calibration factor, obtained from the loaded table. The calibration factor extracted from the table is determined by the aperture of the selected MCPs, the ram direction azimuth and elevation angles in relation to the aperture, and the selected calibration Mach number.

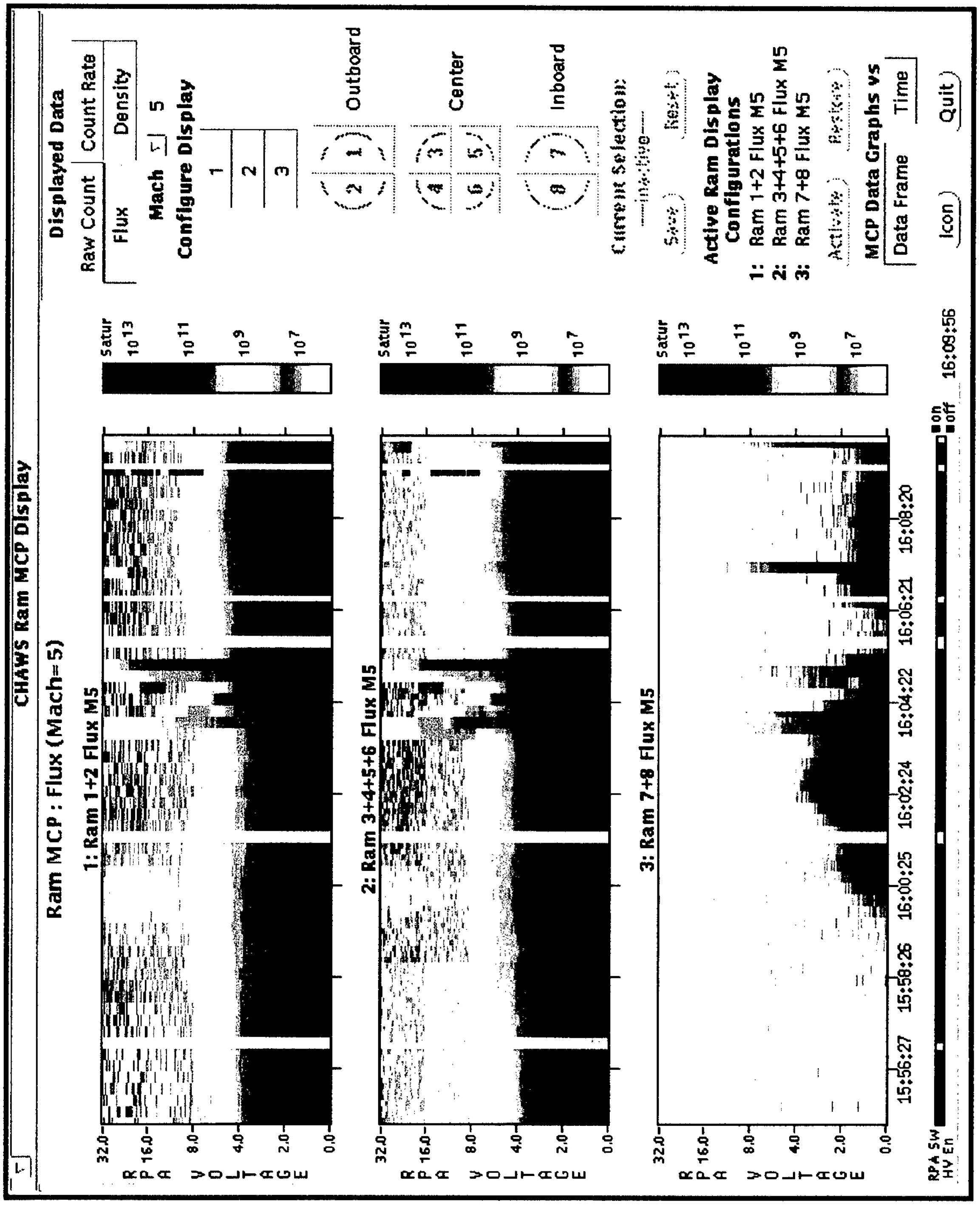


Figure 6. CHAWS MCP Data display.

The resultant 160 values are converted to color indices according to the type of calibration, and displayed vertically in four-pixel wide columns. The Raw Count values are mapped to one of the 32 colors on a linear scale from 0 to 65,0000. Calibrated values of Count Rate, Flux and Density values are mapped to color on a logarithmic scale, where the upper and lower limits are defined at program compilation time.

For each of the three raster images, two types of line graph displays are available, "Data Frame" and/or "Time", for a maximum of six concurrent line graph displays. The user-selected line graph type is invoked by a mouse pointer selection on the data raster image. A "Data Frame" type line graph produces a plot corresponding to a vertical "slice" of the raster image at the mouse pointer position data time. A "Time" type line graph produces a plot corresponding to a horizontal "slice" of the raster image at the pointer position RPA voltage value, centered in a two-minute time span. The line graph display is described in more detail in a following section.

4.10 CHAWS LANGMUIR DATA DISPLAY

The CHAWS Langmuir Data display, shown in Figure 7, presents three parallel color raster images of data from the Langmuir probe. The first of these raster images presents a summarized form of the data from the eight MCP units mounted on sides and end of the Langmuir probe. The second presents the six Langmuir current values, and the third, the applied Langmuir voltage.

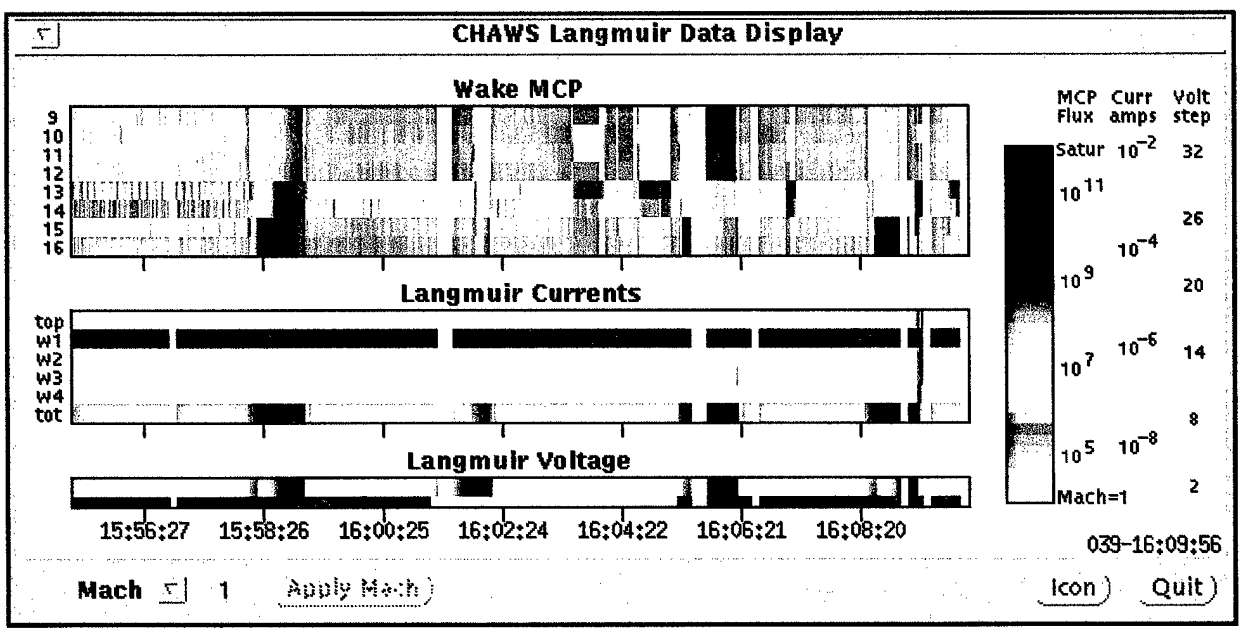


Figure 7. CHAWS Langmuir Data display.

The first image is composed of the Flux-calibrated data from the Wake MCP units, presented in eight parallel color raster image strips, where each CHAWS data frame is displayed in four 1-pixel wide columns. This MCP data is displayed in the Flux calibration only for the individual MCP units. The user does have the option to change the Mach number of the Flux calibration. The procedure for the Flux calibration of the MCP data is identical to that in the CHAWS MCP Data Display process, but is displayed in a different format.

For each CHAWS data frame, the expanded counts of the 160 RPA steps for the MCP unit is multiplied by the appropriate dwell time correction. The flux calibration factor is extracted from the calibration table based on the MCP aperture, the ram direction azimuth and elevation angles in relation to the aperture, and the selected Mach number.

The Wake MCP data for each MCP is displayed horizontally, in four 1-pixel wide columns. The colors for these four columns are determined from scaling of four sets of flux value averages, logarithmically scaled according to the prescribed exponential limits defined during program compilation. These four sets of flux value averages are defined as :

- Set 1 : Average of Flux values for RPA steps 1 - 96
- Set 2 : Average of Flux values for RPA steps 97 - 128
- Set 3 : Average of Flux values for RPA steps 129 - 144
- Set 4 : Average of Flux values for RPA steps 145 - 160

These RPA step ranges correspond to the four Langmuir voltage steps time sequence.

The second image is composed of the Langmuir Current values, presented in six parallel color raster image strips. These six current values are the "Top", "Waist 1", "Waist 2", "Waist 3", "Waist 4", and "Total". Each CHAWS data frame of current data is displayed in four 1-pixel wide columns. The colors for these four columns are determined from scaling of four sets of current value averages, logarithmically scaled. As for the Wake MCP data values, these four sets of current averages are defined as :

- Set 1 : Average of Current values for RPA steps 1 - 96
- Set 2 : Average of Current values for RPA steps 97 - 128
- Set 3 : Average of Current values for RPA steps 129 - 144
- Set 4 : Average of Current values for RPA steps 145 - 160

The third image is composed of the Langmuir Voltage values, also displayed in four 1-pixel wide columns for each CHAWS data frame. The voltages for each of the four voltage steps are averaged, and the nearest equivalent voltage step number (between 1 and 32, inclusively) for the Langmuir sweep profile is determined. The resultant step is directly mapped to the corresponding color. The four voltage averages are defined as:

- Set 1 : Average of Voltage values #1- #4
- Set 2 : Average of Voltage values #5 and #6
- Set 3 : Voltage value #7
- Set 4 : Voltage value #8

In a normal full Langmuir voltage sweep of eight CHAWS data frames, all 32 colors of the scale are used. Included at the lower portion of the Langmuir voltage raster image is a solid strip of color indicating the current Langmuir voltage sweep profile number. The colors of the profile indicator strip relate to the maximum voltage in the sweep profile.

The raster images of the Wake MCP, current and Langmuir voltage provide a qualitative data analysis capability, showing the large-scale features of the data. The user may perform quantitative data analysis with the available line graph displays. Three concurrent line graph displays are may be activated, one for each of the Wake MCP, Current and Langmuir Voltage raster images. Each of these may be invoked using the mouse pointer to directly select the data feature to be studied in detail. The mouse cursor, when over the raster image, will bracket a time slice of data to be plotted. The line graph display is described in more detail in the following section.

4.11 CHAWS LINE GRAPH PROCESS

The CHAWS Line Graph process displays the data from the CHAWS MCP or Langmuir Data Display processes in line graph form in a variety of forms, depending on the data and display type selected. In all forms, the user may examine each value plotted in the graph. As the user moves the mouse pointer within the line graph area, the value of the nearest plotted data point is annotated, along with additional information such as time, data frame clock cycle, RPA Step number, etc. Alternatively, the user may select to have all the information written to a specified ASCII file. This file may be viewed on-line, printed, or used as input to an external program.

As the selection of a particular data feature on the CHAWS MCP or Langmuir Data Display raster images may not always be precisely on target, the user may adjust the time of the line graph being displayed forwards or backwards in single data frame increments. When plotting data over several data frames, the user may also adjust the data parameter being plotted, such as the RPA step number. The user always has the option to re-select any region on the same raster image for changing the line graph time and data parameter being displayed.

The line graph forms are largely dependent on the data parameter being plotted and the line graph "parent" data display. Those line graphs that are invoked from the CHAWS MCP Data Display process produce plots of the MCP data values versus "Time" and "7.5 seconds" or "RPA Steps".

Invoking from the Langmuir Data Display process produces line graph plots of Wake MCP, Langmuir Current and/or Langmuir Voltage values versus "One Minute", equaling eight CHAWS data frames. The user may toggle the Langmuir data plot time durations between "One Minute" (eight data frames) and "7.5 seconds" (one data frame). On each graph, the plotted data values are averaged and/or spaced appropriately over the time duration of each data frame time interval, mimicking the data collection time sequence.

The Langmuir Wake MCP plot may be toggled between versus "One Minute", "RPA Steps" and "7.5 Seconds". The Langmuir Current and Langmuir Voltage plots may be toggled between versus "One Minute" and "7.5 Seconds". The Langmuir Current plot has an additional capability to plot the current versus Langmuir voltage.

The line graph plot forms and their data processing details are summarized below :

- *vs RPA Steps*- Figure 8 displays Ram or Wake MCP data versus a linear scale of RPA steps of 1-160. Available for CHAWS MCP data when displayed in Raw Counts; Available for Langmuir Wake MCP data.

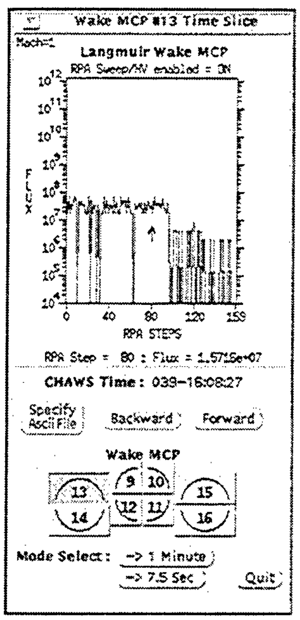


Figure 8. CHAWS line graph vs. RPA steps.

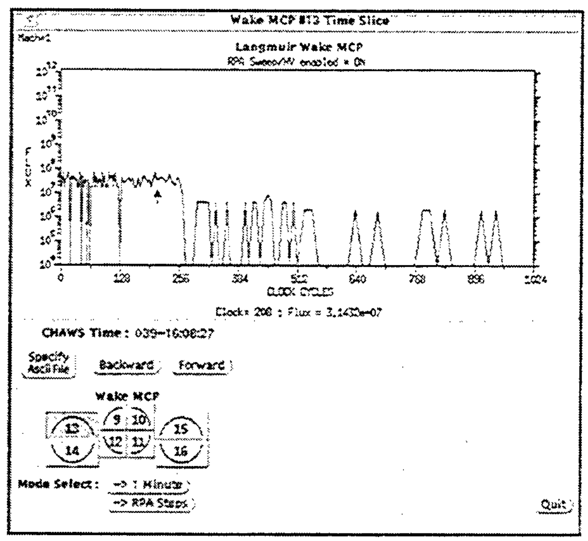


Figure 9. CHAWS line graph vs. 7.5 seconds, clock cycle form.

- *vs 7.5 seconds* - Figures 9 and 10 display one data frame of Ram or Wake MCP data, Current values or Langmuir voltages versus a linear scale of 1-1024 clock cycles or 0-32 RPA volts. The 160 data values (8 for Langmuir voltages) are plotted at their appropriate clock cycle positions. Available for CHAWS MCP data when displayed in all calibrations except Raw Counts; Available for Langmuir Wake MCP, Langmuir Current and Voltage data.

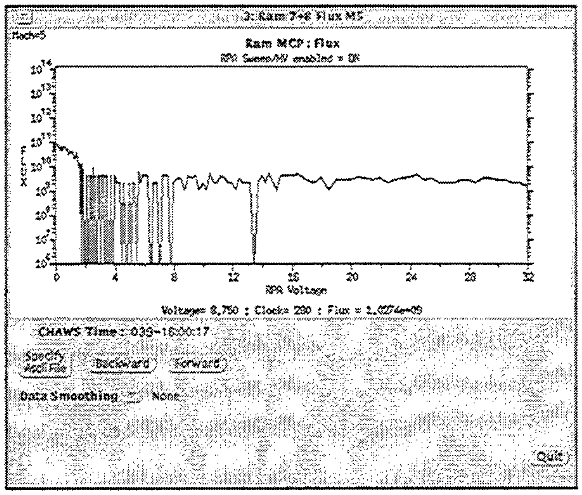


Figure 10. CHAWS line graph vs. 7.5 seconds, RPA voltage form.

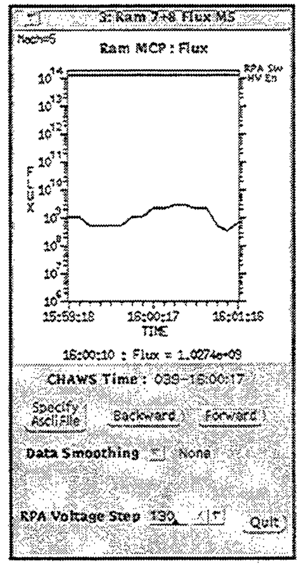


Figure 11. CHAWS line graph vs.time.

- *vs Time* - Figure 11 displays Ram or Wake MCP data versus a linear time scale for 17 CHAWS data frames, about two minutes. One data value, for the selected RPA step number, is displayed for each data frame. Available for CHAWS MCP data only.

- *vs One Minute* - Figures 12, 13, and 14 display eight CHAWS data frames of Wake MCP data, Current values, or Langmuir voltages vs a linear time scale spanning one minute. For each data frames, the 160 data values are presented as 32 points, averaging the values contained in 32-clock cycle spans. All eight of the Langmuir voltage values are displayed. Available for Langmuir Wake MCP, Langmuir Current and Voltage data only.

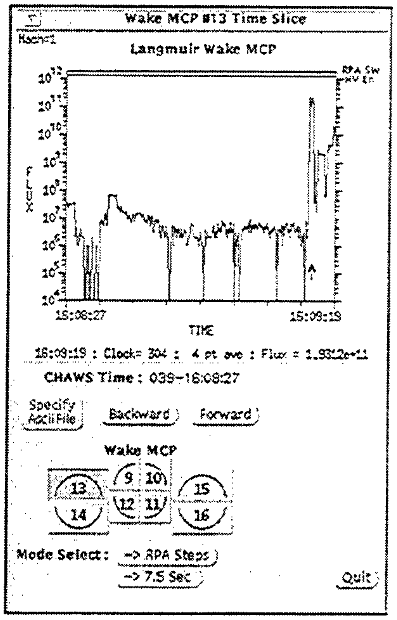


Figure 12. CHAWS line graph vs. one minute for Wake MCP data.

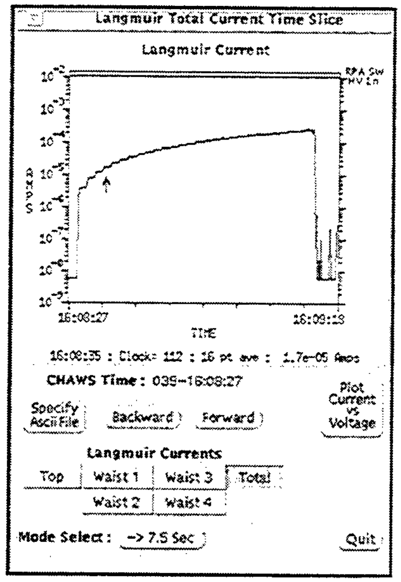


Figure 13. CHAWS line graph vs.one minute for current values.

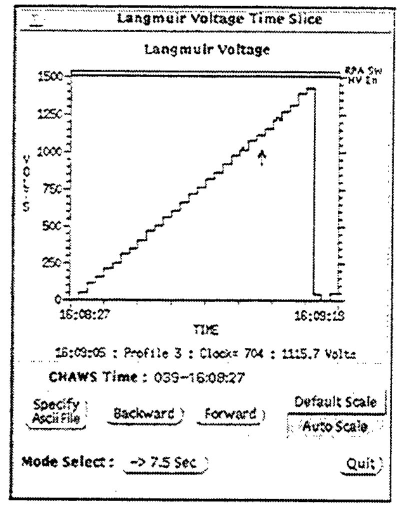


Figure 14. CHAWS line graph vs. one minute for Langmuir voltages.

- *IV curve* - Figure 15 displays average Langmuir current values versus average Langmuir voltage values for eight CHAWS data frames. The plot is automatically scaled. For each data frame, four current/voltage average pairs are plotted, and are defined as:

  Set #1 :
  Current - average over RPA steps 60 - 68
  Voltage - average of voltages #1 thru #4

  Set #2 :
  Current - average over RPA steps 108 - 116
  Voltage - average of voltages #5 and #6

  Set #3 :
  Current - average over RPA steps 132 - 140
  Voltage - voltage #7

  Set #4 :
  Current - average over RPA steps 148 - 156
  Voltage - voltage #8

The current averaging limits were chosen to be in the central portion of each Langmuir voltage step, where it should be free of transitional effects. Available only through special option in display of Langmuir Current data.

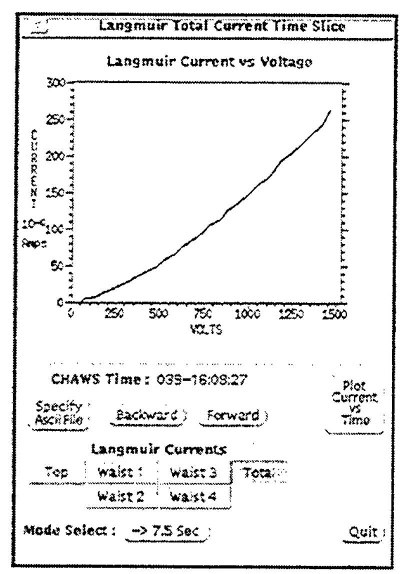


Figure 15. CHAWS line graph IV curve.

4.12 CHAWS RAM DIRECTION DISPLAY

The CHAWS Ram Direction Display process presents numeric values of the WSF ram direction in several different reference frames, and attempts to derive the ram direction based on the Ram side MCP telemetry data values. As shown in Figure 16, a representation of the ram side apertures is displayed with each MCP partition colored based on its relative raw count value.

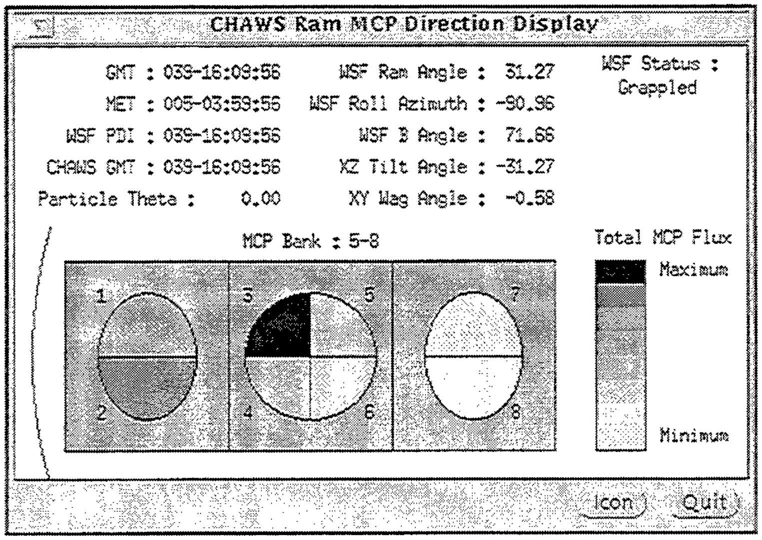


Figure 16. CHAWS Ram Direction display.

The *particle theta* angle is derived from the relation of the Ram side MCP telemetry counts for RPA step 0 only. Based on ratios of these raw telemetry counts, two ratio values of the center versus side aperture MCP units are determined. Based on the magnitude of these two ratios, the *particle theta* angle is obtained from one of two look-up tables of polynomial curve-fitted values.

The WSF LVLH attitude is determined for calculation of the WSF ram and B-field angles. To determine the attitude, the WSF status is determined, as described previously. When *Stowed*, the WSF attitude is determined via transformation of the orbiter LVLH attitude matrix. When *Grappled* by the RMS arm end effector, the WSF attitude in relation to the orbiter body coordinate system is determined through a series of rotations and translations of the six RMS joint angles. The WSF LVLH attitude is calculated then by the application of the orbiter LVLH attitude matrix to the matrix describing the WSF attitude in relation to the orbiter. When *Deployed*, the WSF pitch and roll values are obtained from the WSF telemetry. As no yaw value is measured by the WSF satellite, it is assumed to be 0 degrees. These pitch, yaw and roll values are then applied to the orbiter LVLH matrix to derive an approximation of the WSF LVLH attitude matrix.

From the derived WSF LVLH attitude matrix, the desired angles can then be calculated. The "WSF B-Field Angle" is calculated as the angle between the WSF attitude +X vector and the modeled B-Field line direction vector, as calculated by the Listener or Merge Survey process. The "WSF Ram Angle" is calculated as the angle between the WSF Body +X vector and the orbiter state vector-derived LVLH +X vector. The use of the orbiter LVLH matrix vectors is necessary as no WSF state vectors (position and velocity) are available.

The "WSF Roll Azimuth", "Wag" and "Tilt" angles are simply variations of "WSF Ram Angle", reporting the ram direction angle projected onto three different planes of the WSF body coordinates. The "WSF Roll Azimuth" is the angle between the component of the ram direction in the YZ plane and the -Y axis, increasing in the counter-clockwise direction, as shown in Figure 17. The "Tilt Angle" is the angle between the component of the ram direction in the XZ plane and the +X axis, increasing in the +X to -Z direction. The "XY Wag Angle" is the angle between the component of the ram direction in the XY plane and the +X axis, increasing in the +X to -Y direction.

The Orbiter/WSF Attitude Display also includes the WSF Solar Direction Angles. These angles are annotated as 'Solar Az' and 'Solar El' in the lower left-hand corner of the display window. The "Solar Azimuth" is defined as the angle between the +Z axis and the solar direction component in the YZ plane. See Figure 18. The "Solar Elevation" is defined as the angle between the +X axis and the solar direction vector.

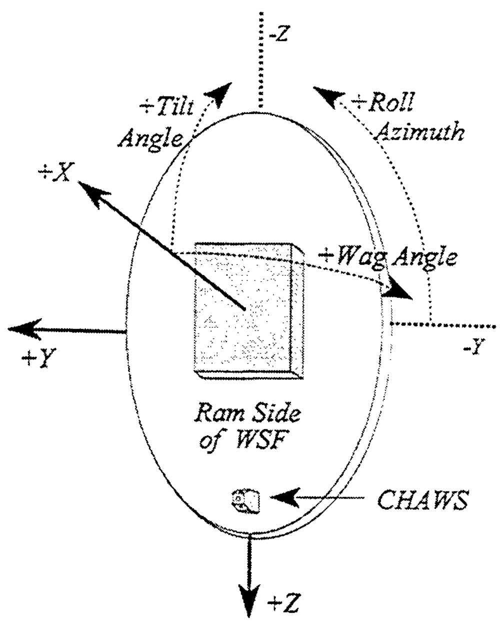


Figure 17. WSF ram direction angles.

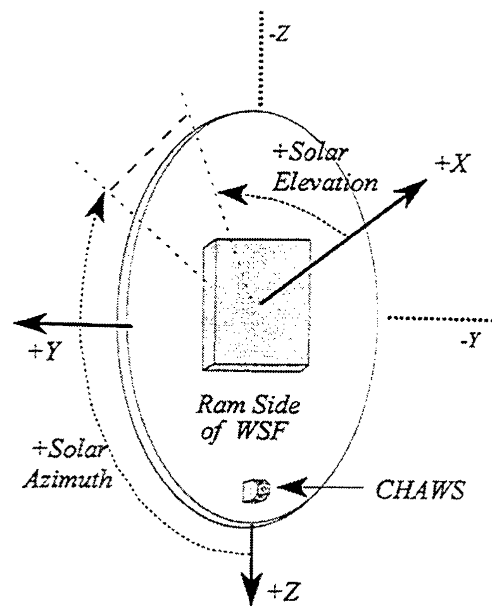


Figure 18. WSF solar direction angles.

4.13 TRAJECTORY DISPLAY

The trajectory display, shown in Figure 19, depicts the current position and flight path of the orbiter on a world map with day/night terminators. The current latitude, longitude, altitude and attitude values are displayed numerically. The ram and B-field angles to the orbiter bay normal are calculated and also displayed numerically.

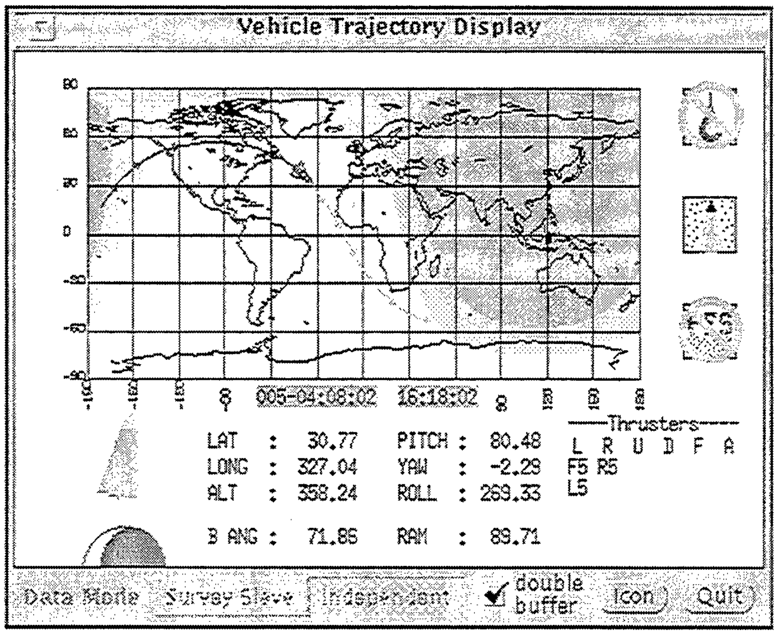


Figure 19. Trajectory display.

During real-time operations the downlinked CAS state vectors are used to construct an orbital element data base. In the postflight data analysis environment, the user may view the orbiter trajectory information in a "Survey Slave" mode or "Independent" mode. When in "Survey Slave" mode, the displayed orbiter information is controlled by the Merged Data Survey process, allowing the user to track the orbiter trajectory information in parallel with the CHAWS instrument data displays. In "Independent" mode, shown in Figure 20, the user selects the time for the orbiter information display, and may view the sub-second thruster firing information. The user may also step the time of the orbiter information display forward or backward in various increments.

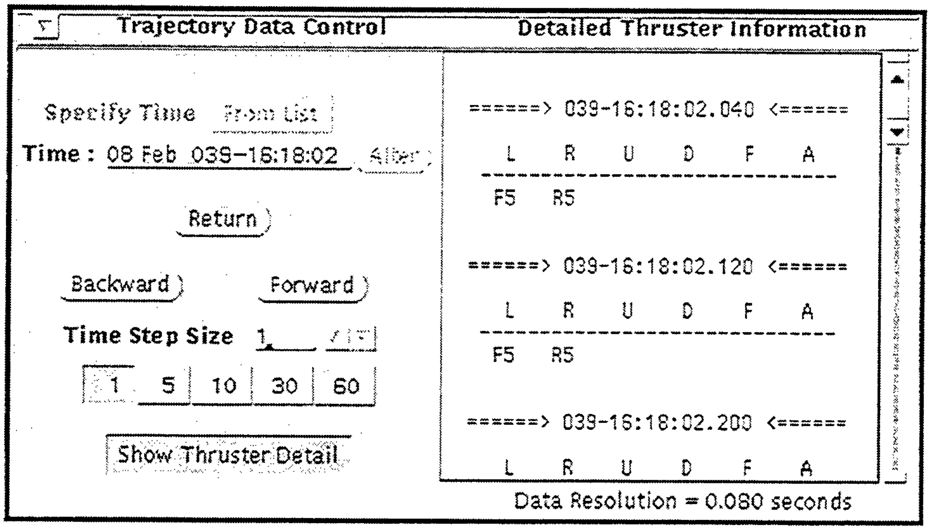


Figure 20. Trajectory display "independent" mode control panel.

4.14 ATTITUDE DISPLAY

The attitude display, shown in Figure 21, presents a three-dimensional depiction of the orbiter in its current attitude. The positions of the orbiter RMS arm and the WSF are also drawn in their respective orientations and positions as indicated by the orbiter data. Small colored plumes, at the appropriate locations of the orbiter, are used to indicate thruster firings, water dumps and/or FES usage. These orbiter events are also indicated through the use of icons and text. The current latitude, longitude, altitude and attitude values are displayed numerically. The ram, sun and magnetic field angles to the orbiter bay normal are also calculated and displayed. An indication of the orbiter being either "Sunlit" or "Eclipsed" is also displayed. The WSF status (*Stowed*, *Grappled* or *Deployed*), attitude values and range to the orbiter are annotated. The spacecraft charging effects value, $\vec{V}\times\vec{B}\cdot\vec{L}$ and the $\vec{L}$ vector magnitude are annotated while the WSF satellite is grappled by the RMS arm. The vector is defined by the line from the mid-point of the top orbiter Main Propulsion System (MPS) engine to the center of the WSF satellite, and is displayed in units of meters. The $\vec{L}$ value is calculated from the orbiter velocity vector ($\vec{V}$, in km/sec) cross the orbiter position local magnetic field vector ($\vec{B}$, in Teslas), dotted with the distance vector ($\vec{L}$, in km). An associated rendezvous profile process, described in a following section, allows the user to view the relative orbiter/WSF positions during deployment and retrieval operations.

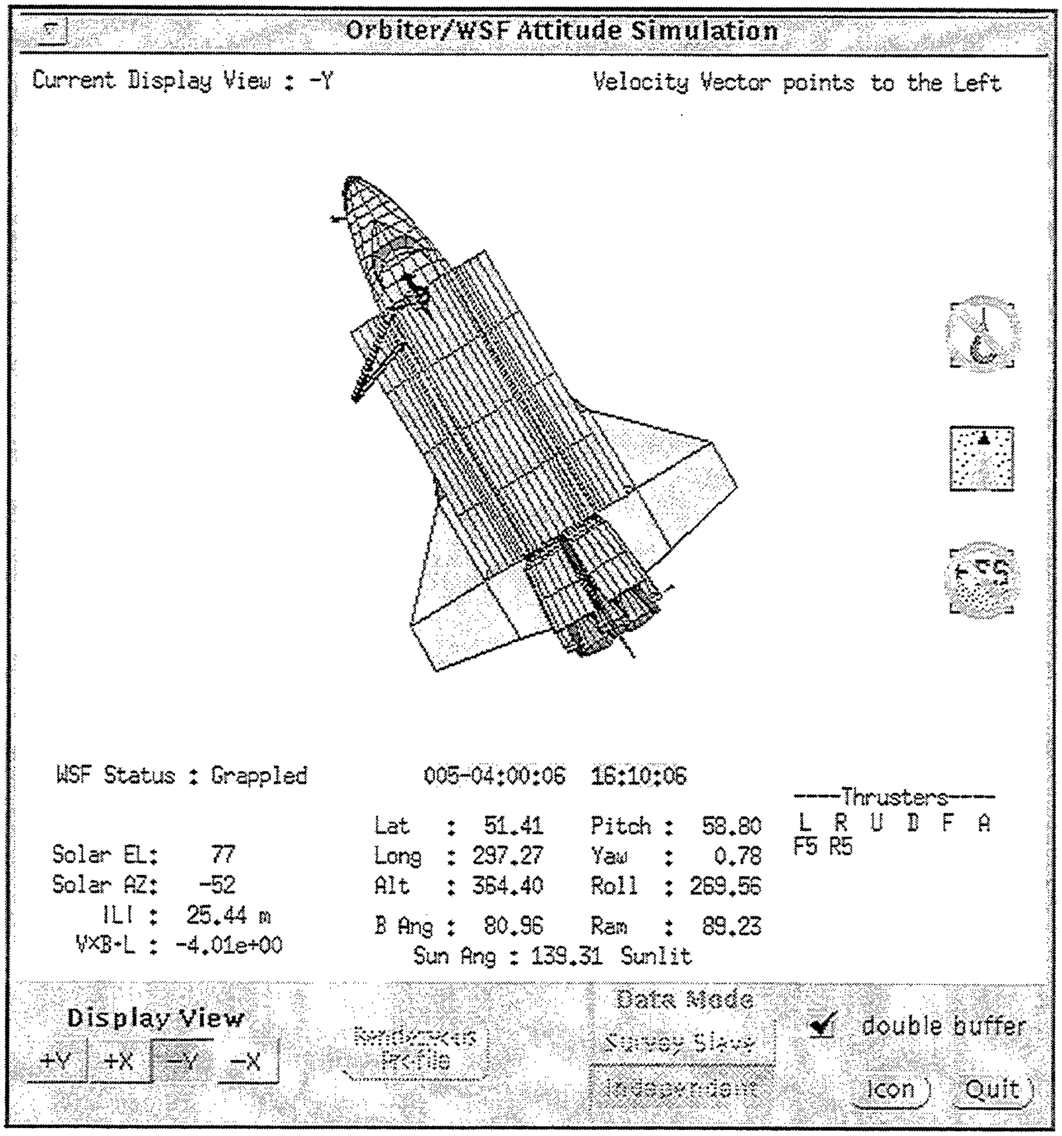


Figure 21. Attitude display.

As with the Trajectory process, the Attitude process allows the user to view the orbiter information in a "Survey Slave" mode or "Independent" mode in the postflight data analysis environment. When in "Survey Slave" mode, the displayed orbiter information is controlled by the Merged Data Survey process, allowing the user to track the orbiter attitude in parallel with the CHAWS instrument data displays. In "Independent" mode, the user selects the time for the orbiter information display, and may view the sub-second thruster firing information. The user may also step the time of the orbiter information display forward or backward in various increments.

4.15 RENDEZVOUS PROFILE

The Rendezvous Profile display, shown in Figure 22, presents a standard R *vs* V profile plot. Using the ranging information supplied to it from the Attitude process, the current time, R, V and absolute range values are annotated, and the current location plotted. The plot may be expanded or reduced in 10% increments, permitting customized scaling. An ASCII log file of all values displayed is automatically generated for later review.

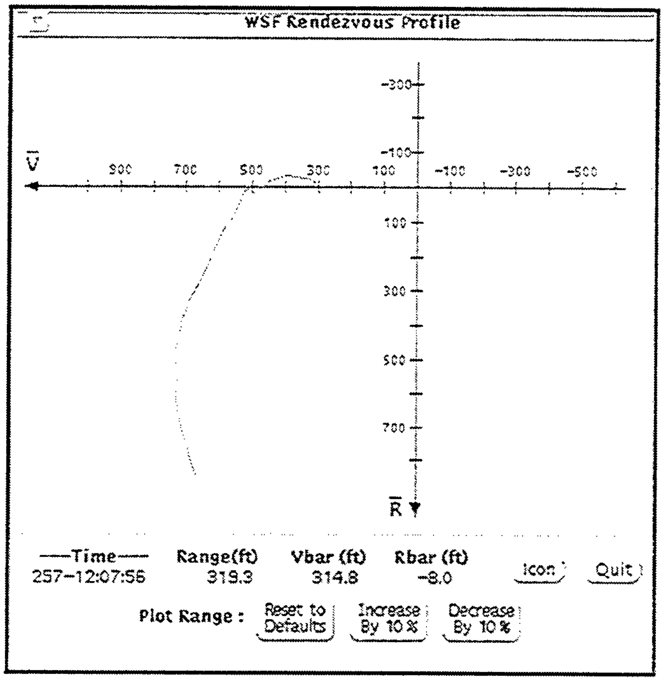


Figure 22. Rendezvous profile display.

4.16 ORBITER EVENT DISPLAY

The Orbiter Event Display process, shown in Figure 23, presents a time-based display of orbiter events. The orbiter thruster firings, water dumps, and FES usage are presented in parallel rows, where the active events are indicated by colored blocks in the appropriate event row or rows. The colors used are the same as those used for the plumes in the Attitude Display process. The Orbiter Event Display time scale is identical to those in the CHAWS MCP and CHAWS Langmuir Displays.

The 44 orbiter thrusters are divided into 14 thruster groups, as defined by NASA and shown in Figure 24. The firing of any of the thrusters within a group is indicated by a colored block in the corresponding group row. The color indicates the type of thruster fired: red for the "primary" Reaction Control System (RCS) thrusters, magenta for Vernier RCS

thrusters, or orange for both. The "Supply" and "Waste" water dump and FES "A" & "B" activity indicators are presented in separate rows and colors of blue, yellow, and green, respectively. Information detailing the thruster locations and groupings, water dump and FES valve locations are provided in an information window, accessible via the "Info..." button.

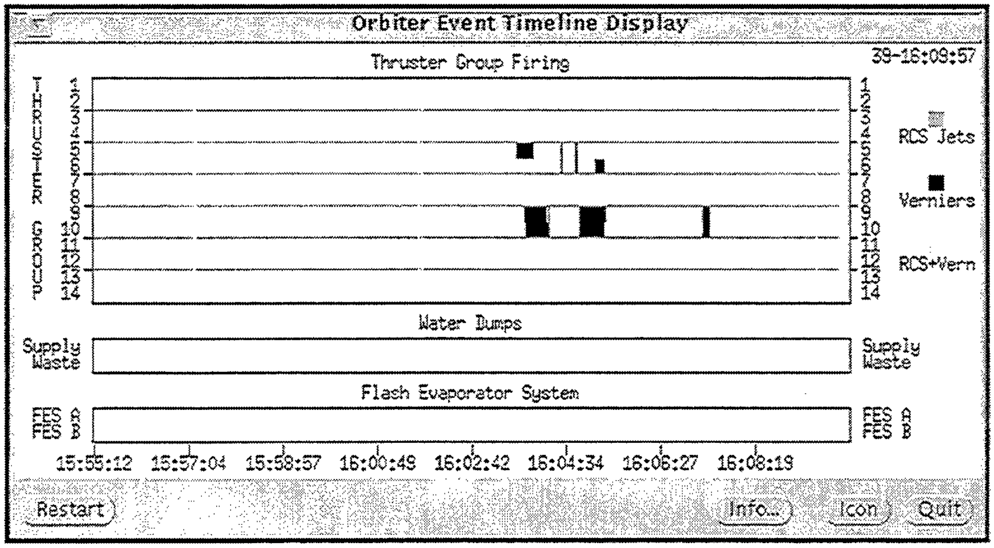


Figure 23. Orbiter event display.

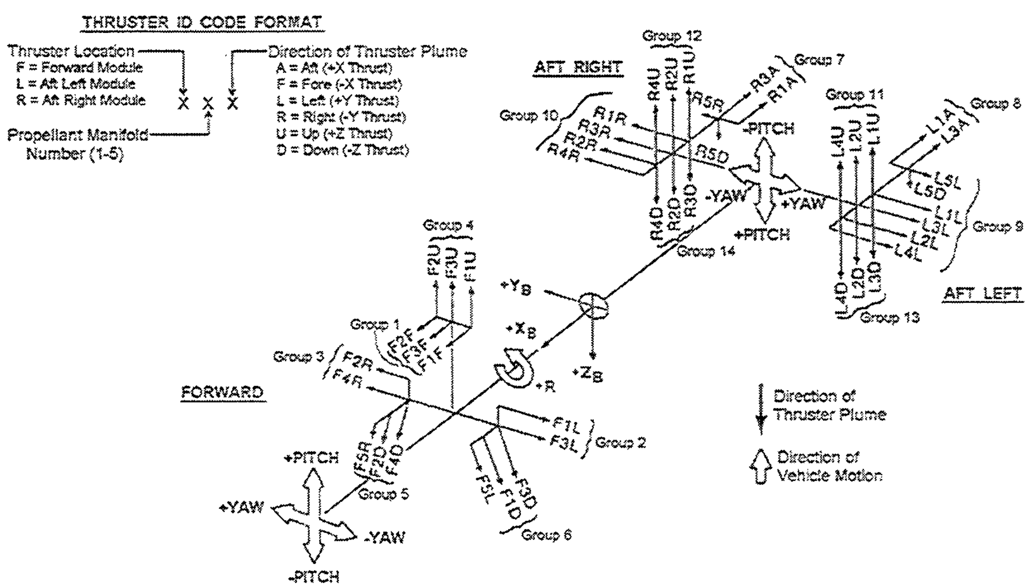


Figure 24. Orbiter thruster locations and groupings.

The user may graphically "pick" data on the display with the left or right mouse button to view more detailed event information. A scrolling text window is invoked, displaying the water dump status, FES status and sub-second thruster firing information for the selected time. An example is shown in Figure 25. The user may step forward or backwards in time, as in the line graphs.

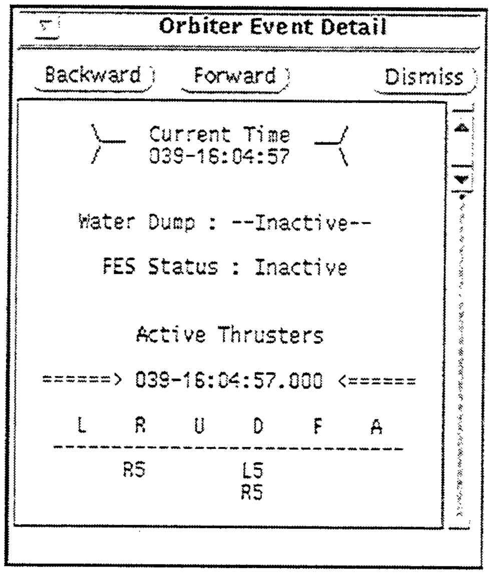
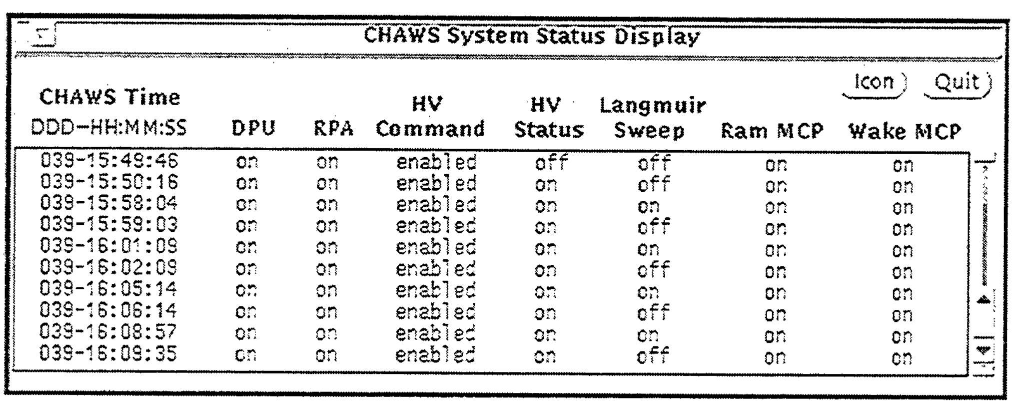


Figure 25. Orbiter event detail.

4.17 CHAWS STATUS DISPLAYS

The CHAWS status processes track changes in the CHAWS instrument operation. The current settings are presented in a scrolling text window, as shown in Figure 26. When these logs exceed 400 lines, their contents are saved in ASCII files for future reference. The CHAWS System Status process logs changes to the CHAWS instrument states, such as the DPU state, RPA state, HV status. The CHAWS Langmuir Probe Status process logs detailed changes in the Langmuir probe status, such as the HV status, sweep status and voltage sweep number.

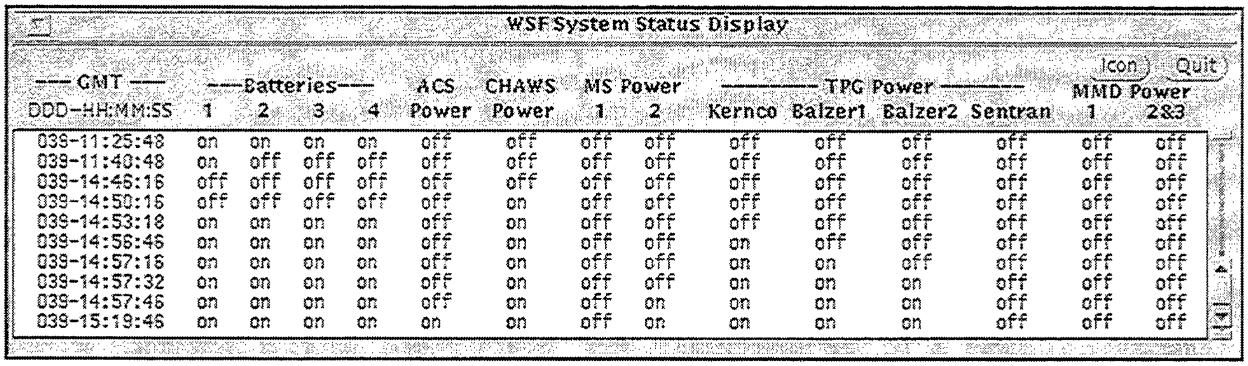
4.18 WSF STATUS DISPLAYS



CHAWS Time DDD-HH:MM:SS	DPU	RPA	HV Command	HV Status	Langmuir Sweep	Ram MCP	Wake MCP
039-15:49:46	on	on	enabled	off	off	on	on
039-15:50:16	on	on	enabled	on	off	on	on
039-15:58:04	on	on	enabled	on	on	on	on
039-15:59:03	on	on	enabled	on	off	on	on
039-16:01:09	on	on	enabled	on	on	on	on
039-16:02:09	on	on	enabled	on	off	on	on
039-16:05:14	on	on	enabled	on	on	on	on
039-16:06:14	on	on	enabled	on	off	on	on
039-16:08:57	on	on	enabled	on	on	on	on
039-16:09:35	on	on	enabled	on	off	on	on

Figure 26. CHAWS system status display.

The WSF status processes track changes in the status of the WSF system operation, presented in a scrolling text window, shown in Figure 27. When these logs exceed 400 lines, their contents are saved in ASCII files for future reference. The WSF System Status process logs changes to battery usage and device power settings. This process lists the current state of the WSF battery usage indicators and instrument power indicators. The WSF Command Echo process reports any system commands echoed through the telemetry. The WSF CDD Status process logs the identification of the data packets transmitted through the WSF telemetry Continuous Data Devices.


WSF System Status Display

Icon Quit

GMT	Batteries				ACS	CHAWS	MS Power		TPG Power				MMD Power	
DDD-HH:MM:SS	1	2	3	4	Power	Power	1	2	Kernco	Balzer1	Balzer2	Sentran	1	2&3
039-11:25:48	on	on	on	on	off	off	off	off	off	off	off	off	off	off
039-11:40:48	on	off	off	off	off	off	off	off	off	off	off	off	off	off
039-14:46:16	off	off	off	off	off	off	off	off	off	off	off	off	off	off
039-14:50:16	off	off	off	off	off	on	off	off	off	off	off	off	off	off
039-14:53:18	on	on	on	on	off	on	off	off	off	off	off	off	off	off
039-14:56:46	on	on	on	on	off	on	off	off	on	off	off	off	off	off
039-14:57:16	on	on	on	on	off	on	off	off	on	on	off	off	off	off
039-14:57:32	on	on	on	on	off	on	off	off	on	on	on	off	off	off
039-14:57:46	on	on	on	on	off	on	off	on	on	on	on	off	off	off
039-15:19:46	on	on	on	on	on	on	off	on	on	on	on	off	off	off

Figure 27. WSF System Status display.

4.19 TRENDING

The Trending display allows the user to examine the CHAWS (shown in Figure 28) or WSF (shown in Figure 29) health and status values over time. For either data mode, the user selects one of the available data parameters from a scrolling list to be plotted as a function of time. The user specifies a starting time and time duration, producing the appropriate graph with an automatically scaled data axis. Once plotted, the user may alter the selections and generate a new graph, or may "edit" the currently displayed graph. The range of both the time and data axes may be shortened graphically using the mouse pointer, or the user may specify the minimum and maximum limits of the data axis. The Trending process window may be shortened, allowing multiple Trending displays with different parameters to be stacked for parallel comparison.

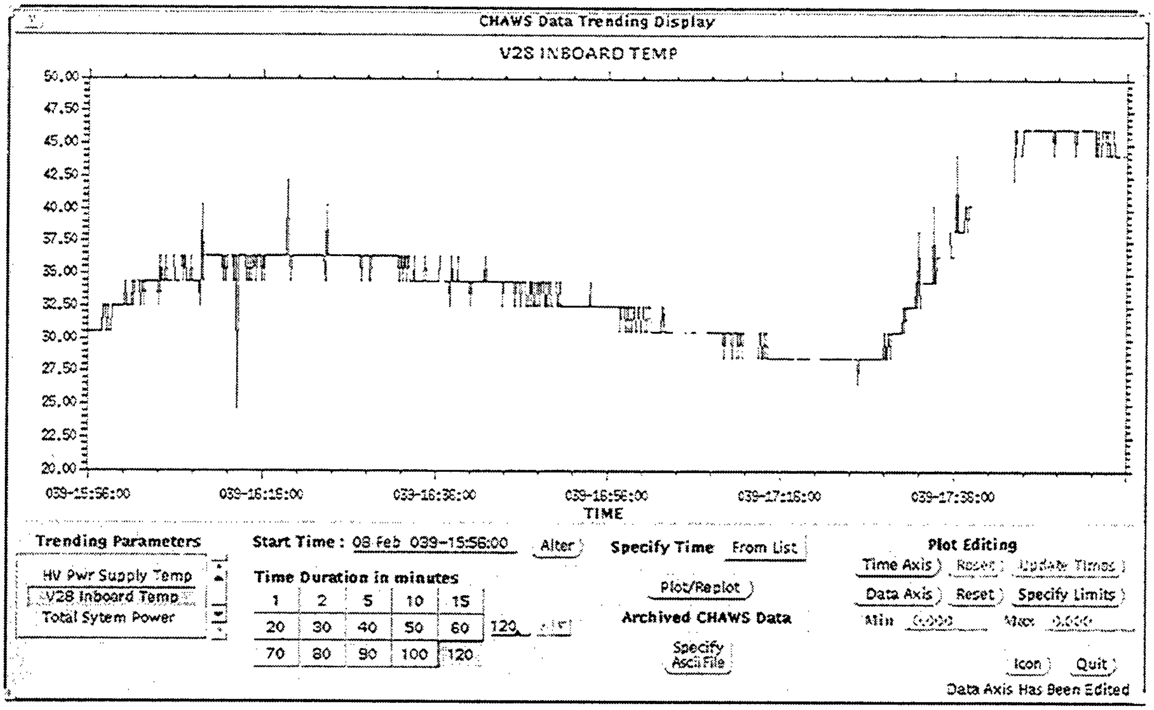


Figure 28. CHAWS data trending display.

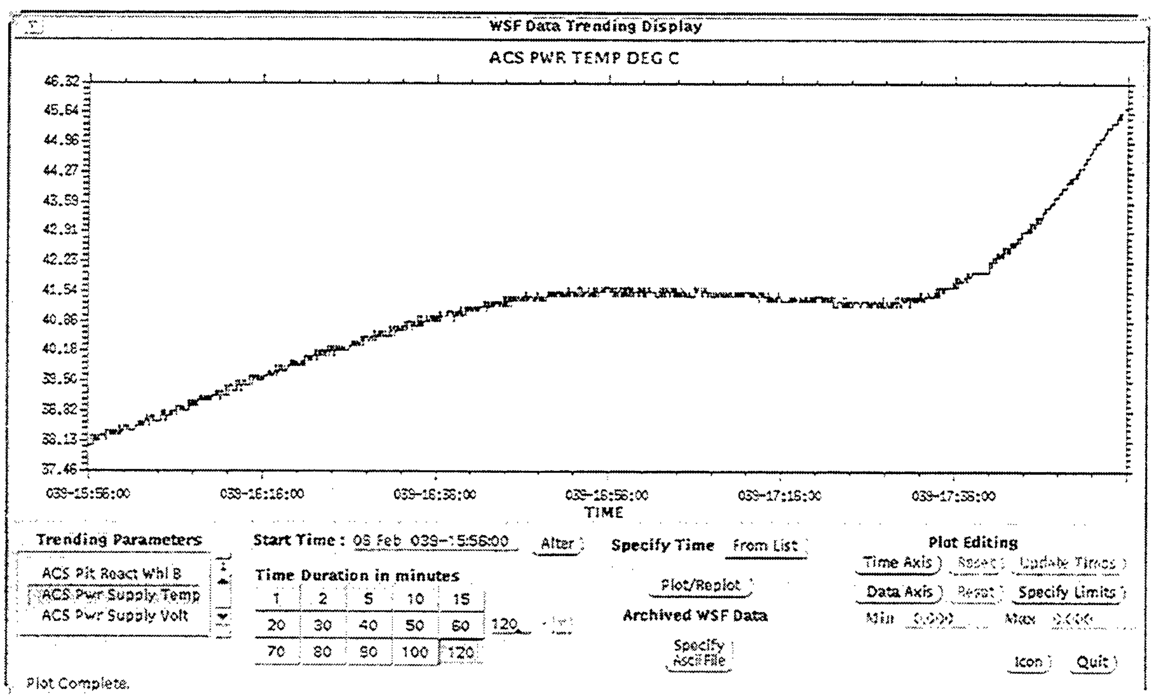


Figure 29. WSF data trending display.

4.20 CALIBRATION GLOBE

The CHAWS Calibration Globe display, shown in Figure 30, presents the calibration values for a specific CHAWS aperture, calibration type, and Mach number as a color-coded sphere based on the aperture ram direction elevation and azimuth angles. The color scaling is automatically adjusted to match the range of the calibration values. The user selects the CHAWS aperture, calibration type, and/or Mach number for display. The user may alter the viewing position, specified in terms of the aperture ram direction elevation and azimuth, via slider controls. Alternatively, the user may query the orbiter/WSF/CHAWS data loaded in the shared memory to calculate the current ram direction angles for the selected CHAWS aperture. A pullout line graph feature is available (shown in Figure 31), and displays dual line graphs of the calibration values as a slice over elevation at the current azimuth and a slice over azimuth at the current elevation.

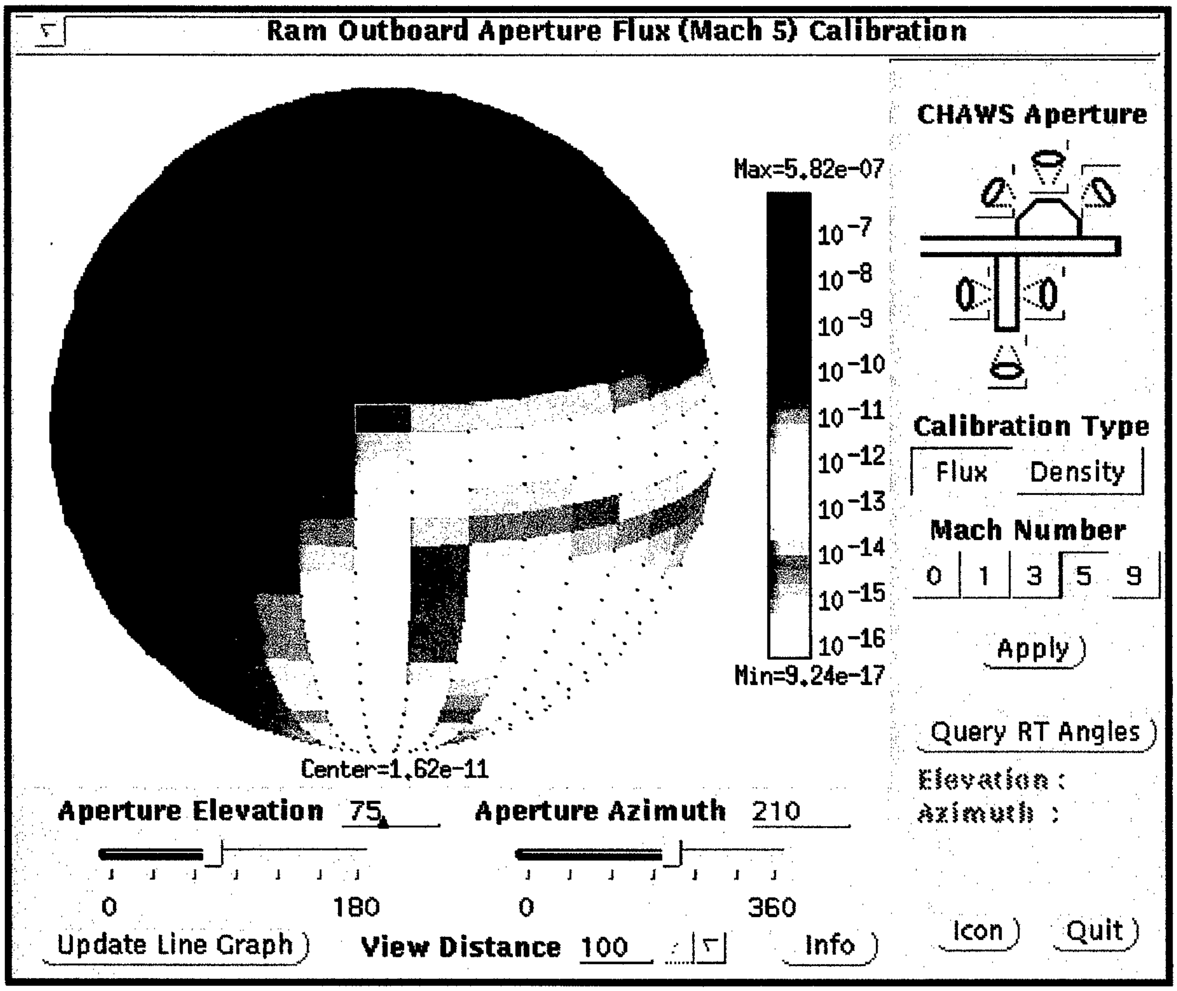


Figure 30. CHAWS calibration globe display.

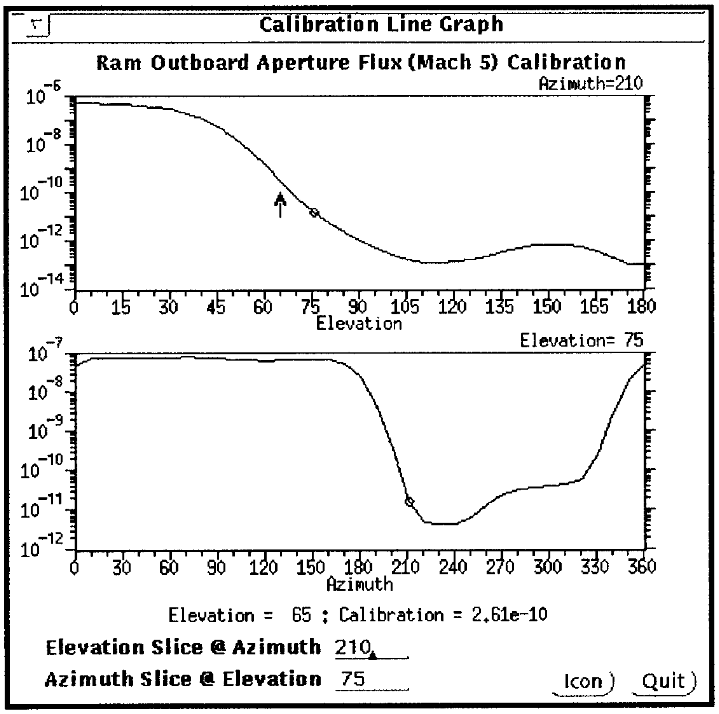


Figure 31. Calibration Line Graph display.

The calibration values displayed are based on the geometric function (G_{flux} and $G_{density}$) values read from the calibration files in the CHAPS installation directory. The 20 calibration files are organized on the basis of aperture side (ram or wake), calibration type (flux or density), and the five available Mach numbers (0, 1, 3, 5 and 9). The averaged geometric factor for an isotropic distribution (G_0), the *Prefactor*, which incorporates the aperture area and efficiency factors, and the orbital velocity (V_d) values are also contained in each of these files. The displayed values are calculated as in the equations below :

$$\textit{flux calibration value} = G_{flux}(\textit{Mach}, \textit{Azimuth}, \textit{Elevation}) \times G_0 \times \textit{Prefactor}$$
$$\textit{density calibration value} = G_{density}(\textit{Mach}, \textit{Azimuth}, \textit{Elevation}) \times G_0 \times \textit{Prefactor} \times V_d$$

5. CHUNKS

CHUNKS is an interactive or batch-mode program used to access the CHAWS data base files and produce ASCII files of tabulated data calculations and plot files. This program is meant to complement the capabilities of CHAPS by being able to scan the post flight data for correlations and compute physical variables of interest. The CHUNKS program shares the same calibration and calculation methods as used in CHAPS, maintaining consistency between the two packages.

The data base contains information describing the shuttle orbiter (CAS), the Wake Shield Facility (WSF), and the CHAWS experiment. The CHUNKS routines for reading these data base files are derived from and are compatible with those of CHAPS. The CHUNKS

program marches through the data base, by stepping CAS GMT time, and checks to see if there is a matching WSF or CHAWS time and if so, it reads in the corresponding structure records. Selected variables can be extracted from the structures and printed out, along with various derived variables. All of the CHAWS structure variables are accessible, and selected variables are available from CAS and WSF. The CHUNKS program has been used extensively to survey the CHAWS missions and to test out algorithms, e.g. for the ambient density and temperature.

An input parameter file specifies the data parameters chosen to be extracted and manipulated. Up to five output files can be requested for displaying orbiter (CAS), wake shield facility(WSF), and CHAWS information. The CHAWS data records typically span 7.5 seconds and the information for this period is designated as frame data. Each frame contains data for the 160 channel micro-channel plates (MCP), which is designated as channel data. The frame and channel information can be accessed separately and the data comes out in different files. There is also an option to output a file with the estimated current-voltage (IV) characteristics along with calculated flags for identifying the valid sweep times. The CHUNKS inputs and outputs are described in more detail below.

5.1 CHUNKS INPUT

The CHUNKS input specifications are read from a file called "inputs". An example is shown in Figure 32. The first two lines of the file specify the start and stop time for the run. For these lines, the first column must be a string specifying a the type of time, the second column is a string giving the actual dates (day, hour, minute and seconds), and the third column is a caption. In addition to writing named files, the CHUNKS program also can divert data to standard output. The next four input lines control the data which is sent to standard output by means of on/off switches. The data corresponds to that chosen from the CAS, WSF or CHAWS records, which is specified below. There is also a merge option that can put the above information all on a single line, or output each case separately.

For the rest of the input file, the data typically consists of three columns of information. The first column specifies the name of the output file, the second column contains a number relevant to the variable chosen, and the third column has the name of the selected variable. The first column string must be one of the following strings:

- *output_CAS* - for CAS information
- *output_WSF* - for WSF information
- *output_CHA_frame* - for CHAWS frame information
- *output_CHA_channel* - for CHAWS channel information within a frame
- *output_CHA_current* - for CHAWS current-voltage information

The meaning of the number in the second column, depends on a "logical" format switch. If this switch is "off", the output variables are ordered according to the number in the second column: if it is on, they are arranged by the order in which they are selected in the

file and the number (zero or one) acts merely as an on/off switch. The string in column three specifies the variable names and must be chosen from a prescribed list. A reference file is provided to CHUNKS users with all the currently available names. Each of the above files has a corresponding on/off switch to control the output. The *output_CHA_channel* file should be turned on with caution, since it can quickly become very large.

```
start_date    39:16:01:20     day:hr:min:sec
 stop_date    39:16:02:24     day:hr:min:sec

stdio_cas            1    stdio_switch
stdio_wsf            1    stdio_switch
stdio_chaws          1    stdio_switch
stdio_merge          1    stdio_switch

logical              0    on/off

output_CAS           1    on/off

output_CAS           0    GMT_date
output_CAS           1    GMT_ut

output_CAS           2    latitude
output_CAS           0    longitude
output_CAS           0    altitude
output_CAS           0    sun_angle

output_WSF           1    on/off

output_WSF           1    b_angle
output_WSF           2    ram_angle
output_WSF           0    roll_azimuth
output_WSF           3    xz_tilt
output_WSF           0    xy_wag
output_WSF           0    L_mag
output_WSF           4    vxb_dot_L
output_WSF           0    solar_el
output_WSF           0    solar_az

output_CHA_frame     1    on/off

output_CHA_frame     9    CHAWS_time.seconds_counter
output_CHA_frame     0    CHAWS_time.day
output_CHA_frame     0    CHAWS_time.hours
output_CHA_frame     0    CHAWS_time.minutes
output_CHA_frame     0    CHAWS_time.seconds

output_CHA_frame    10    PDI_time.seconds_counter
output_CHA_frame     0    PDI_time.day
output_CHA_frame     0    PDI_time.hours
output_CHA_frame     0    PDI_time.minutes
output_CHA_frame     0    PDI_time.seconds
output_CHA_frame     1    langmuir_profile_number

output_CHA_frame     2    langmuir_sweep_status
output_CHA_frame     0    DPU_status
output_CHA_frame     0    RPA_status
output_CHA_frame     0    hv_status
output_CHA_frame     0    hv_command_status
output_CHA_frame     0    wall_temp
output_CHA_frame     0    log_temp
output_CHA_frame     0    hv_power_supply_temp
output_CHA_frame     0    v28_inboard_temp
output_CHA_frame     0    total_system_current
output_CHA_frame     0    mcp_status_voltage
output_CHA_frame     0    v0dc_ref
output_CHA_frame     0    v5dc_ref

output_CHA_frame     4     voltage[0]
output_CHA_frame     5     voltage[7]
output_CHA_frame     6     current[0]
output_CHA_frame     7     current[7]

output_CHA_frame     0    ram_den01
output_CHA_frame     3    ram_den2345
output_CHA_frame     0    ram_den67

output_CHA_frame     0    ram_hp_eng01
output_CHA_frame     8    ram_hp_eng2345
output_CHA_frame     0    ram_hp_eng67

output_CHA_channel   1    on/off

output_CHA_channel   0    waist_current[0]
output_CHA_channel   0    waist_current[1]
output_CHA_channel   0    waist_current[2]
output_CHA_channel   0    waist_current[3]
output_CHA_channel   0    top_current
output_CHA_channel   5    total_current

output_CHA_channel   1    estimated_time

output_CHA_channel   2    lswp_counter
output_CHA_channel   3    sweep_voltage
output_CHA_channel   4    langmuir_voltage
output_CHA_channel   0    rpa_voltage

output_CHA_current   1    on/off
```

Figure 32. Sample CHUNKS 'inputs' file.

Since the CHUNKS program accesses the standard data base, it must read the same auxiliary files for as CHAPS, which contain path information. The CHUNKS default is to read these files from the current directory, but this can be modified by including the path as a command line argument. A command line argument can also be used to switch between batch and GUI mode. Documentation for CHUNKS is available on line in the form of README files.

5.2 CHUNKS OUTPUT

The CHUNKS output data files will be briefly described below. An example is shown in Figure 33. The format of the files *output_CAS*, *output_WSF*, *output_CHA_frame* and *output_CHA_channel* is similar. A header section appears listing the column numbers and the corresponding names of the chosen variables. The actual data lines follow, with the variables shown in the order selected.

File *output_CAS* contains selected variables extracted from the CAS record. This file contains direct positional information for the shuttle such as latitude, longitude, altitude, pitch, yaw and roll as well as the calculated sun angle.

File *output_WSF* contains Wake Shield information. This includes the ram and magnetic field angles and the wag and tilt orientation angles of the WSF facility along with the sun elevation and azimuth angles.

File *output_CHA_frame* (see Figure 34) can contain variables from the CHAWS structure record along with some derived quantities. The direct variables include various status flags, trending variables and Langmuir currents and voltage, and raw MCP counts. The derived quantities include the rates, fluxes and densities for ram and wake sides. These values are based on an average of the first three channels of the RPA data. The calibrations used are the same as for CHAPS and the data is available for each of the six ram and wake apertures.

File *output_CHA_channel* gives CHAWS data for the 160 RPA channels. At the start of each frame a header line is printed which designates the frame start time. The variables include the counts, rates, fluxes and densities for the full MCP range as well as some constructed quantities such as the clock cycle and the corresponding RPA sweep voltage.

The file *output_CHA_current* contains CHAWS current-voltage characteristics, based on a "stencil" algorithm taken from CHAPS. This algorithm calculates the average currents and voltages for channels selected by a fixed pattern to give a reasonable representation of the IV curve. Along with voltages and currents, the date is printed and a flag is output that labels the sweep, which typically is accumulated over several frames.

The CHUNKS print to standard output has a sequence of header lines giving the output variables selected for the run, based on the CAS, WSF, CHAWS frame CHAWS channel and CHAWS current input selections. This is followed by a section which echoes the chosen start and stop times and indicates which of the CAS, WSF or CHAWS frame variables are to be diverted to standard output and whether this data is to be merged to single lines. The data values for each case are printed in columns in the order specified by the input file. Test runs have been made at various time intervals to validate that CHAPS and CHUNKS output the same information for common cases.

```
Write requests read from file 'inputs'
logical = 0

output_CAS on/off = 1
 column     1  /                        GMT_ut
 column     2  /                      latitude
Write to file -> output_CAS

output_WSF on/off = 1
 column     1  /                       b_angle
 column     2  /                     ram_angle
 column     3  /                       xz_tilt
 column     4  /                     vxb_dot_L
Write to file -> output_WSF

output_CHA_frame on/off = 1
 column     1  /        langmuir_profile_number
 column     2  /          langmuir_sweep_status
 column     3  /                    ram_den2345
 column     4  /                     voltage[0]
 column     5  /                     voltage[7]
 column     6  /                     current[0]
 column     7  /                     current[7]
 column     8  /                 ram_hp_eng2345
 column     9  /     CHAWS_time.seconds_counter
 column    10  /       PDI_time.seconds_counter
Write to file -> output_CHA_frame

output_CHA_channel on/off = 1
 column     1  /                 estimated_time
 column     2  /                   lswp_counter
 column     3  /                  sweep_voltage
 column     4  /               langmuir_voltage
 column     5  /                  total_current
Write to file -> output_CHA_channel

output_CHA_current on/off = 1

Write to file -> output_CHA_current

Run control settings:
 start_day =  39, start_time    /  16    1  20 / 57680 sec
  stop_day =  39,  stop_time    /  16    2  24 / 57744 sec
 stdio_cas     = on
 stdio_wsf     = on
 stdio_chaws   = on
 stdio_merge   = on

begin read_merged_files, at date: day = 39, gmt = 57680
 57699   55.08    61.18   21.07   -21.07   -3.96   5   1   3.07e+04   35.36    41.39   5.78e-07   9.69e-07   3.19
57699   57710
 57706   55.22    61.93   21.07   -21.07   -3.97   5   1   3.26e+04   43.39    49.67   9.15e-07   1.29e-06   3.06
57706   57716
 57714   55.37    62.38   20.34   -20.34   -3.93   5   1   3.31e+04   51.68   135.29   1.22e-06   5.12e-06   3.06
57714   57724
 57721   55.50    62.95   20.01   -20.01   -3.92   5   1   3.28e+04  154.90   233.33   4.84e-06   1.08e-05   3.19
57721   57732
 57729   55.64    63.63   19.55   -19.55   -3.90   5   0   3.54e+04  252.94   331.37   1.08e-05   1.81e-05   3.06
57729   57740
 57736   55.76    64.25   19.30   -19.30   -3.89   5   0   3.54e+04  174.51     2.23   1.71e-05   5.87e-09   3.06
57736   57744
..hit CAS time stop at day = 39, sec = 57744
 57744   55.88    64.95   18.96   -18.96   -3.88   5   0   3.57e+04    2.23     2.23   5.87e-09   5.87e-09   3.06
57744   57754
..end read_merged_files, at date: day = 39, gmt = 57745
 User Halt Requested.
```

Figure 33. Sample CHUNKS 'output' file.

```
column      1  /          langmuir_profile_number
column      2  /            langmuir_sweep_status
column      3  /                      ram_den2345
column      4  /                       voltage[0]
column      5  /                       voltage[7]
column      6  /                       current[0]
column      7  /                       current[7]
column      8  /                   ram_hp_eng2345
column      9  /       CHAWS_time.seconds_counter
column     10  /         PDI_time.seconds_counter
# 1   # 2     # 3       # 4      # 5       # 6         # 7      # 8    # 9     #10
  5     1   3.07e+04    35.36    41.39   5.78e-07   9.69e-07   3.19   57699   57710
  5     1   3.26e+04    43.39    49.67   9.15e-07   1.29e-06   3.06   57706   57716
  5     1   3.31e+04    51.68   135.29   1.22e-06   5.12e-06   3.06   57714   57724
  5     1   3.28e+04   154.90   233.33   4.84e-06   1.08e-05   3.19   57721   57732
  5     0   3.54e+04   252.94   331.37   1.08e-05   1.81e-05   3.06   57729   57740
  5     0   3.54e+04   174.51     2.23   1.71e-05   5.87e-09   3.06   57736   57744
  5     0   3.57e+04     2.23     2.23   5.87e-09   5.87e-09   3.06   57744   57754
```

Figure 34. Sample CHUNKS 'output_CHA_frame' file.

6. REFERENCES

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